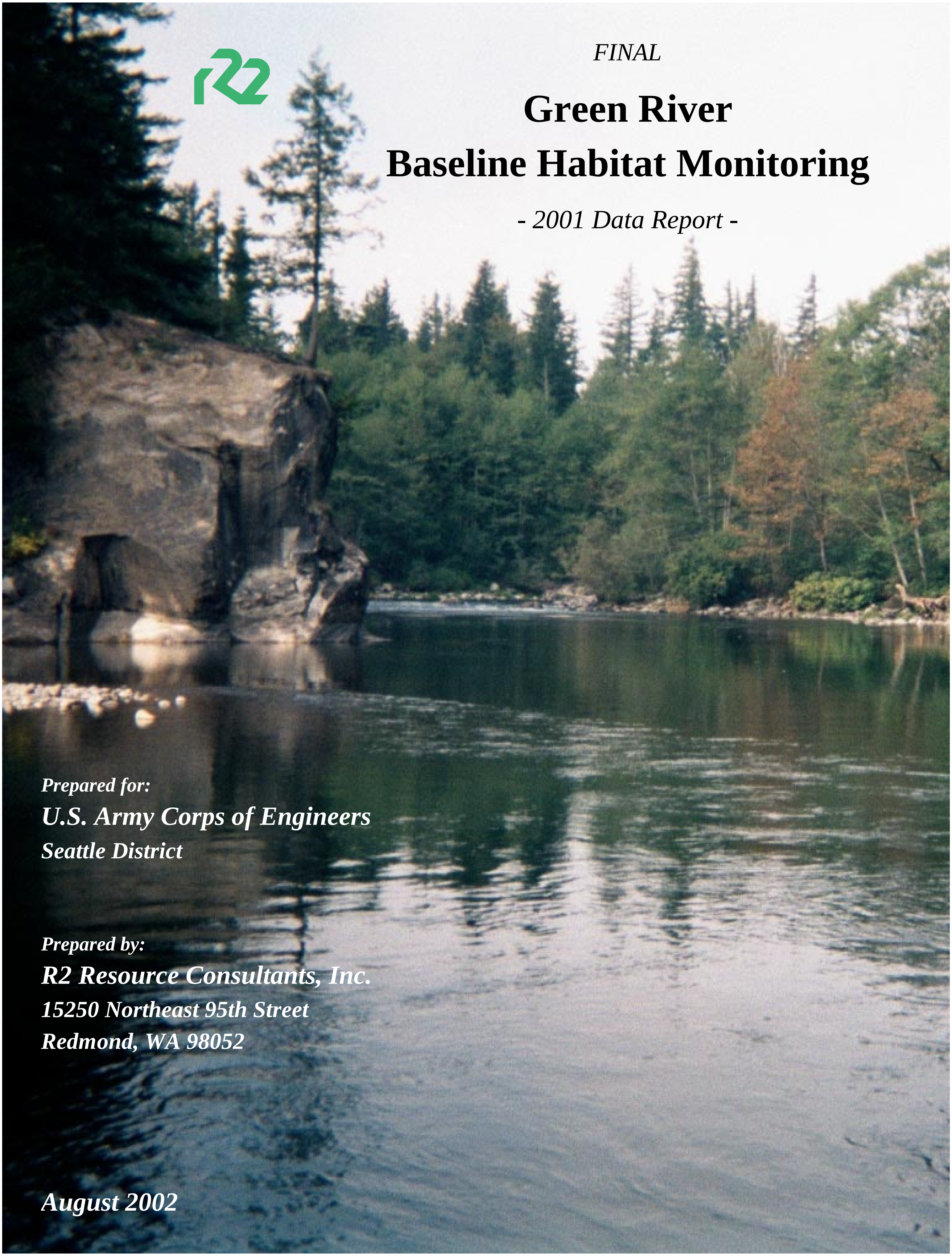

FINAL

Green River Baseline Habitat Monitoring

- 2001 Data Report -

Prepared for:

U.S. Army Corps of Engineers

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FIGURES

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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers (USACE) Seattle District is developing an integrated monitoring program to evaluate the effect of two major restoration projects underway in the Green River basin near Seattle Washington – the Howard Hanson Dam Additional Storage Project (AWSP) and the Green-Duwamish Ecosystem Restoration Project (GD ERP). This report describes the results of the first in a series of monitoring studies to be conducted as part of the Green River Habitat Restoration Evaluation Program. Monitoring efforts described in this report are intended to provide baseline data that will be used to track trends in habitat conditions in the mainstem middle Green River before, during and after large-scale habitat restoration projects have been implemented. The mainstem middle Green River physical habitat monitoring described here will be repeated at five to ten year intervals for a period of 50 years. This monitoring will be complemented by additional studies focusing on other important aspects of riverine habitat.

The mainstem Green River baseline physical habitat monitoring study is intended to track reach scale trends in habitat conditions. Commonly used habitat inventory protocols were reviewed to identify monitoring parameters that were both responsive to the types of activities to be implemented under the AWSP and GD ERP, and that could be measured with sufficient accuracy to track change over time. The proposed methodology was presented to all major parties involved in habitat and salmon management at a workshop convened in May 2001. Key monitoring parameters and appropriate measurement techniques were discussed and finalized at the workshop.

Baseline habitat monitoring was completed in August and September 2001. Key parameters quantified throughout the survey area during reach scale habitat monitoring include bankfull width, canopy cover, pool habitat unit location and dimensions, large woody debris (LWD), and riffle particle size distributions. In addition, other habitat types were identified and mapped. Existing and potential gravel storage sites in each reach were located and described. Habitat surveys encompassed the entire study area from Howard Hanson Dam at RM 64.5 to Auburn Narrows at RM 32. The study area was subdivided into six reaches based on channel morphology.

Reach 1: RM 64.5 (Howard Hanson Dam) to RM 61.0 (Tacoma Headworks)
Reach 2: RM 61.0 (Tacoma Headworks) to RM 57 (Kanasket State Park)
Reach 3: RM 57 (Kanasket State Park) to RM 45 (Flaming Geyser State Park)

Reach 4: RM 45 (Flaming Geyser State Park) to RM 40 (Newaukum Creek)
Reach 5: RM 40 (Newaukum Creek) to RM 38 (Loans Levee)
Reach 6: RM 38 (Loans Levee) to RM 32 (Auburn Narrows)

Data analysis consisted of the generation of simple statistics including the average bankfull width, wetted width, canopy cover and LWD frequency. The spacing of pools by reach length, percent of pools formed by LWD, and the D_{50} at randomly selected pebble count sites were also calculated for each reach.

The bankfull channel width ranged from 33 meters in Reach 1 (RM 64.5 to RM 61) to 45 m in Reach 6 (RM 38 to RM 32). Overhead canopy cover was generally about 15 percent, except in Reach 3 (the Green River gorge) where it averaged 26 percent.

Pool spacing ranged from nine channel widths per pool in Reach 3 to 34 channel widths per pool in Reach 4. Pools generally accounted for between 18 and 27 percent of the total habitat area, except in Reach 4 where they represented only 6 percent of the total habitat area. In Reaches 5 and 6, many of the pools present were formed by wood. In Reaches 1, 2, 3, and 4 pools were formed almost exclusively by bedrock. Bedrock-formed pools tended to be substantially deeper than pools formed by bedforms or LWD.

Large woody debris were most common in Reaches 5 and 6, both of which contained one or more large log jams composed of more than 100 pieces of LWD. Wood frequencies (LWD per channel width) ranged from 0.6 (equivalent to approximately 24 pieces/mile) in Reaches 5 and 6 to 0.1 (equivalent to approximately 6 pieces/mile) in Reach 1. Key size pieces as defined by Perkins (1999) were rare throughout the study area, ranging from a total of 11 in the 12-mile long Reach 3 to one in Reach 1. Key pieces contained in the large jams in Reaches 5 and 6 were not tallied individually.

In general, gravel was abundant in Reaches 5 and 6, where the dominant riffle particle size was 56 mm and 42 mm respectively. Gravel was also common in Reach 4, but large storage sites such as point and transverse bars were absent and pool tailouts tended to consist primarily of cobbles. Substantial amounts of gravel were evident in pool tailouts, small point bars and along channel margins downstream of a large landslide near RM 49 in Reach 3. Upstream of that source gravel was scarce. In Reaches 1 and 2, gravel deposits at pool tailouts were rare, and several low gradient riffles with empty storage sites were identified.

The mainstem Green River Habitat Monitoring Program also included a Quality Assurance/ Quality Control (QA/QC) program, including equipment calibration and standardization, repeat surveys, comparison of estimated and measured LWD attributes and review of data entry and calculations.

The results of the QA/QC surveys provide guidance on which habitat attributes are most suitable for long-term reach scale monitoring, and quantitative information on the magnitude of change required to detect statistically significant trends resulting from management actions. Each habitat unit originally identified as a pool during habitat surveys was also identified as a pool in QA/QC surveys, confirming that the overall number and spacing of pool habitat units is an appropriate reach scale monitoring parameter. Comparison of individual pool attributes including, length, width, residual depth and surface area exhibited a high degree of variability. This result is consistent with similar analyses of repeat reach scale habitat surveys conducted elsewhere in the Pacific Northwest, and confirms that measurement of changes in individual habitat units requires intensive effort and is thus most suitable when applied to short channel segments. Results of ANOVA testing for pebble count data collected during baseline habitat monitoring of the mainstem middle Green indicate that counts of 100 randomly selected pebbles is an adequate sample size in channel types that typically exhibit well-sorted substrate (e.g., Reaches 4, 5, and 6). However, in steeper reaches with poorly sorted substrate (e.g., Reaches 1, 2, and 3) larger sample sizes are required to adequately characterize the sample population. Data generated through comparison of estimated and measured LWD indicate that trained observers can accurately classify LWD using ocular estimates after a suitable calibration sample.

1. INTRODUCTION

Habitat alteration and/or loss have contributed to large-scale declines in the number and geographic distribution of both resident and anadromous fish inhabiting the Pacific Northwest (Nehlsen et al. 1991; Weitkamp et al. 1995; Johnson et al. 1999). In general, headwater tributaries have been impacted by forest practices and lower tributaries and mainstem rivers have been impacted by agriculture and/or urbanization. Diking for flood control, draining and filling of freshwater and estuarine wetlands, and sedimentation due to forest practices and urban development are cited as problems throughout Puget Sound Area (WDFW et al. 1994). Blockages by dams, water diversions, and shifts in flow regime due to hydroelectric development and flood control projects are major habitat problems in some basins. The Puget Sound Salmon Stock Review Group provided an extensive review of habitat conditions for several of the salmonid stocks in Puget Sound and concluded that reductions in habitat capacity and quality have contributed to escapement problems for Puget Sound chinook, citing evidence of curtailment of tributary and mainstem habitat due to dams, and losses of slough and side-channel habitat due to diking, dredging, and hydromodification (Cramer et al. 1999).

The Green River basin has experienced many of the impacts noted above. Land and water use activities including logging, agriculture, urbanization, municipal and industrial water use, and flood control have all affected processes controlling the flow of water, sediment, energy and nutrients through the basin. These processes govern the underlying production potential of the system and directly influence fish and their habitat. As a consequence, many natural features of the Green River's aquatic habitats have been compromised, reduced or lost.

The U.S. Army Corps of Engineers (USACE) Seattle District and their local sponsors are implementing two major habitat restoration projects in the Green River basin near Seattle Washington – the Howard Hanson Dam Additional Storage Project (AWSP) and the Green-Duwamish Ecosystem Restoration Project (GD ERP).

The U.S. Army Corps of Engineers (USACE) completed construction of Howard Hanson Dam (HHD) at River Mile RM 64.5 on the Green River in 1962. The project is currently operated to provide fall and winter flood control and summer low flow augmentation for fish resources. In 1989, the USACE began studies to determine if Howard Hanson Dam (HHD) could be used to meet municipal and individual water supply needs as part of an Additional Water Storage Project. The AWSP was subjected to extensive agency review and a collaborative decision making process involving the National Marine Fisheries Service (NMFS), U. S. Fish and

Wildlife Service (USFWS), Washington State Department of Ecology (Ecology), Washington Department of Fish and Wildlife (WDFW), Tacoma Public Utilities (Tacoma) and the Muckleshoot Indian Tribe (MIT). This process resulted in a phased adaptive management plan that provides early outputs of water supply and restoration benefits with an opportunity to review and adjust the project as experience is gained. Key elements of the AWSP restoration and mitigation program include experimentation, monitoring and data analysis followed by adjustment of management and operation practices in response to knowledge gained through the monitoring process.

The AWSP restoration and mitigation components consist of improved downstream fish passage facilities, flow management, gravel nourishment, side-channel reconnection, and placement of anchored and unanchored LWD structures. Construction of fish passage facilities is scheduled to be completed in 2006. Construction of habitat mitigation and restoration projects is scheduled to begin in 2002. These project components will be implemented over several years, and may extend beyond the initial 5-year construction period.

In partnership with King County, the cities of Tukwila, Kent, Auburn, Seattle, Tacoma and Renton, the Muckleshoot and Suquamish Tribes, agencies, and local interests, the USACE has also been developing the Green Duwamish Ecosystem Restoration Project (GD ERP) to address ecosystem degradation problems throughout the Green River basin. Specific project objectives include:

- Enhance/restore degraded habitats for anadromous fish
- Restore ecosystem functions and processes
- Address limiting factors to fish and wildlife production

The GD ERP consists of 45 individual projects, to be implemented over a 10 year construction period. Individual projects include reconnection of off-channel habitats, placement of LWD, removal of fish passage barriers and restoration of riparian zones and wetlands adjacent to the river. The GDERP will also supplement the AWSP gravel nourishment program, providing for additional gravel placement.

The USACE is currently developing an integrated monitoring program to evaluate the effects of the AWSP and GD ERP, and to facilitate adaptive management of the two projects. The monitoring programs are being developed cooperatively, and will collectively be known as the

Green River Habitat Restoration Evaluation Program. The monitoring program will include both reach scale and site-specific monitoring components. Reach scale monitoring will be used to evaluate changes in habitat conditions throughout the middle Green River that result from the combined effect of flow management, gravel nourishment and individual restoration project components. In contrast, site-specific monitoring will focus on documenting the performance and effectiveness of individual restoration project components.

Reach scale monitoring utilizes extensive, low intensity surveys to document the spatial distribution, location, types and general physical characteristics of habitat units and other important habitat features such as LWD. Documenting the number and spacing of pools, the frequency and distribution of LWD, and general substrate conditions over the entire study reach provides a means of determining whether restoration programs are achieving the desired goals for the entire study area, (e.g., increasing the number of large pools). Reach scale monitoring is generally conducted using one of two approaches: semi-quantitative habitat mapping of the entire study reach, or more quantitative subsampling of representative segments that are then extrapolated to the entire study reach. Low intensity mapping of the entire reach was determined to be the preferred for large rivers, such as the Green River. In large rivers, individual habitat units may be thousands of feet-long. Representative reaches of even a mile or more in length may contain only a few habitat units, and alteration of any individual unit by a localized event (e.g., bank failure or breaking up of a LWD jam) can profoundly influence estimates of overall habitat conditions if extrapolated to the reach as a whole.

Reach scale data collected using traditional habitat survey methodologies are poorly suited for documenting changes in individual units or channel segments resulting from restoration efforts. Evaluating the success of individual projects, for example construction of an engineered log jam, therefore requires collection of detailed survey-grade data from the immediate vicinity of the treatment site before and after construction of the project. Multiple cross-sections and precise thalweg profiles are needed to document changes in channel conditions at each site. Data on the condition, volume, stability and distribution of individual pieces of LWD provides important information on the performance and stability of anchored LWD structures. For this reason, the Green River Habitat Restoration Evaluation Program will combine extensive reach scale monitoring with intensive site-specific monitoring of individual project sites. Site-specific monitoring will be developed for individual project components and is beyond the scope of the current study.

This report describes the results of the first in a series of reach scale monitoring studies to be conducted as part of the Green River Habitat Restoration Evaluation Program. The mainstem middle Green River physical habitat monitoring described here will be repeated at five to ten year intervals for a period of 50 years. This monitoring will be complemented by additional studies focusing on other important aspects of riverine habitat such as the availability and quality of lateral and off-channel habitats at various flows over time. It is anticipated that similar habitat surveys to document baseline reach scale habitat conditions in the upper Green River mainstem will be conducted in 2002 or 2003.

The mainstem Green River baseline physical habitat monitoring study is intended to track reach scale trends in habitat conditions. Commonly used habitat inventory protocols were reviewed to identify monitoring parameters that were both responsive to the types of activities to be implemented under the AWSP and GD ERP, and could be accurately measured to track change over time. The proposed methodology was presented to all major parties involved in habitat and salmon management at a workshop convened in May 2001. Workshop attendees included representatives from the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), Washington Department of Fish and Wildlife (WDFW), King County, the Muckleshoot Indian Tribe (MIT) and Tacoma. Key monitoring parameters and appropriate measurement techniques were discussed and finalized at the workshop

This report describes the reach scale habitat monitoring program and presents the results of baseline habitat surveys completed in August and September of 2001. Chapter 2 provides a brief description of the environmental and biological setting of the mainstem Green River. In Chapter 3, baseline habitat monitoring methods developed through the literature review and monitoring workshop are described. A detailed summary of the literature review and meeting notes from the May 2004 Monitoring Workshop is included in Appendix A. The results of the 2001 baseline habitat surveys are presented in Chapter 4. EXCEL spreadsheets containing field forms used to collect data and the complete reach scale habitat inventory database are included as Appendices B and C respectively. Appendix D contains preliminary information on in-channel gravel storage.

2. ENVIRONMENTAL SETTING

2.1 STUDY AREA

The Green River drains an area of 484 square miles located in the southern part of King County Washington. The mainstem Green River flows north and west for approximately 84 miles from its headwaters in the Cascade mountains. At RM 11 the Green River is joined by the Black River to form the Duwamish River before emptying into Puget Sound at Elliot Bay.

Historically, Lake Washington and Lake Sammamish, the Cedar River and the Green and White River all drained to the Duwamish River, forming one of the largest basins in Puget Sound, with a drainage area of 1,639 mi^2. Beginning in 1906, a series of natural and man-made events resulted in the separation of the Duwamish basin into three separate and smaller basins: the Lake Washington Basin (663 mi^2), which includes Lakes Washington and Sammamish and the Cedar River basin; the White River (494 mi^2); and the Green River (484 mi^2). A large flood in 1906 formed a log jam that blocked the confluence of the Green and White Rivers and shifted the majority of the White River flow south into the Puyallup River. Through channelization efforts authorized by the State Legislature in 1909, this shift was made permanent, and the former White River channel was filled. In 1912, a public improvement district diverted the Cedar River into Lake Washington to maintain the elevation of the lake once the Ship Canal was completed, further reducing the drainage area of the Green River basin.

The Green River watershed can effectively be subdivided into three subbasins. The upper Green River extends from the headwaters to Tacoma's Headworks Diversion Dam at River Mile 61.0,[1] which is located 3.5 miles downstream of HHD. The Tacoma Headworks diversion dam currently blocks the upstream migration of anadromous salmonids. The middle Green River includes areas draining to the mainstem between the Tacoma Headworks and the confluence with Soos Creek near Auburn at RM 33.8. The lower Green River continues to the confluence with the Black River at RM 11, which is the upstream extent of the estuary. The baseline habitat monitoring described in this document focuses on mainstem river habitats between RM 32 and RM 64.5 in the middle Green River subbasin (Figure 2-1). The study area was extended to

[1] River mile designations used for this study correspond to those designated by Williams et al. (1975). Subsequent channel changes since development of that measurement system have altered the actual location of specific river miles measured on the ground. However, utilization of the original Williams measurement system maintains comparability with other investigations that have used the Williams river mile designations (e.g., Perkins 1993; USACE 1996).

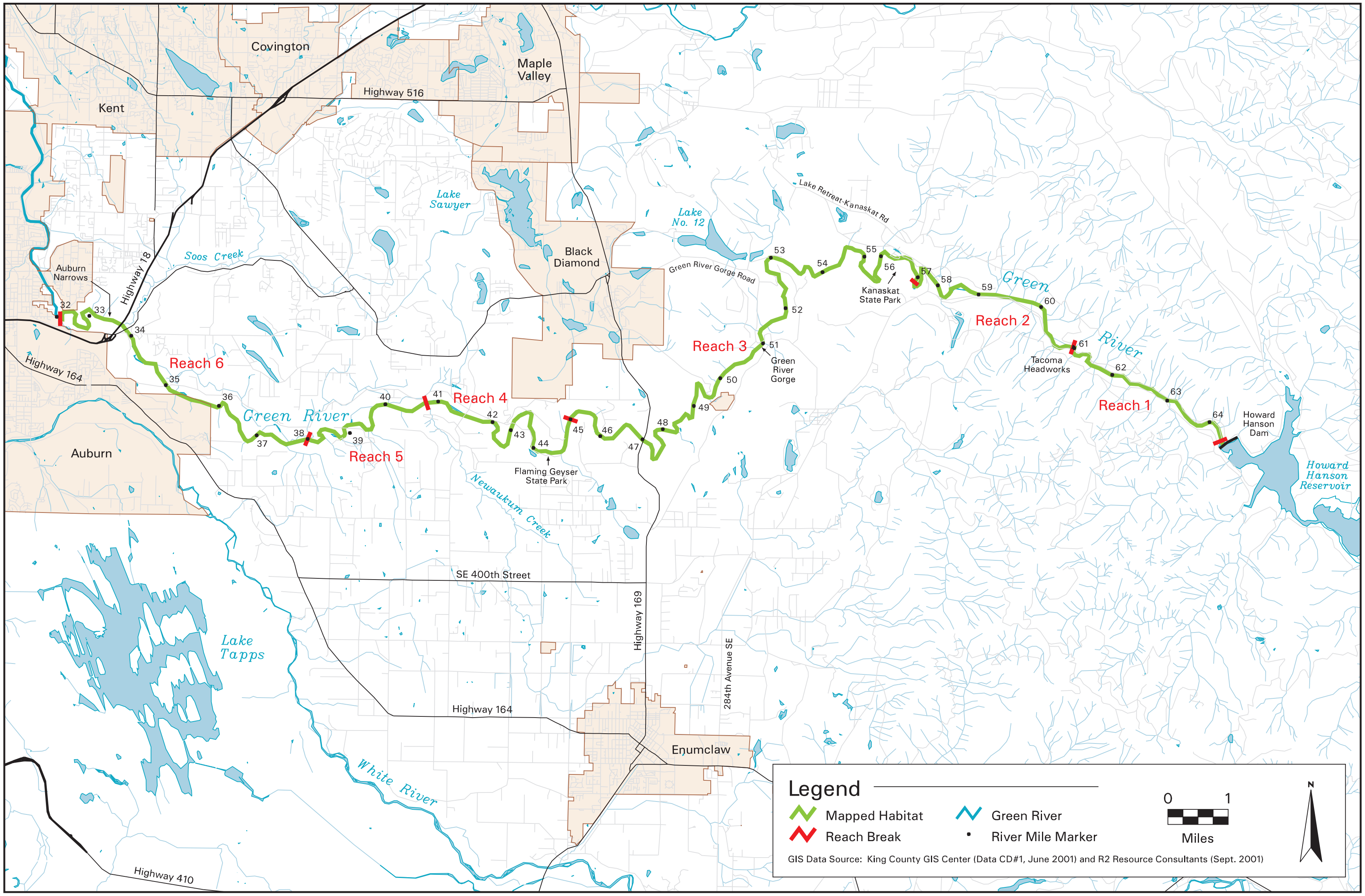


Figure 2-1. Middle Green River physical habitat monitoring area.

include portions of the lower Green River between RM 32 and 33.8, and the upper Green River between RM 61.5 and 64.5 at the request of monitoring workshop participants.

The middle Green River basin lies within the Puget Lowland ecoregion, which is characterized by open hills and flat lacustrine and glacial deposits. This region once contained extensive wetlands; however, the lower portion of the basin was historically developed for agricultural use. Forested areas were cleared for pastureland, and riparian zones were restricted by levees. The Duwamish River historically consisted of extensive saltwater and brackish marshes. Much of the lower basin has since been developed as urban areas and includes the cities of Auburn and Kent (USACE 1996).

Salmonid habitats in the Green River are controlled according to basin-scale characteristics of sediment sources, transport, and deposition, prevailing climate and hydrology. Coarse sediments enter the stream system by means of periodic mass wasting and rock fall and collect in the lower gradient reaches of the upper valley area, where alluvial deposits are temporarily stored and reworked. Fine sediment production in the Green River basin is low relative to other nearby, glacially fed rivers.

The majority of the Green River watershed upstream of the estuary (RM 11) was historically forested. Lowland forests along the mainstem river consisted of stands of western red cedar and hemlock, mixed with younger stands of cottonwood and alder on more frequently disturbed floodplain features. Trees in the riparian zone would fall into the headwater tributaries and mainstem, thereby providing biologic and geomorphic functions such as creating pool habitat, and retaining gravel and organic material.

The upper half of the middle Green River (Reaches 1, 2, and 3) flows through confined mountains and a steep gorge with a channel bed of bedrock, boulders, and occasional patches of gravel. The gorge parent material is relatively erodible sandstone and mudstone, and thus was not an important historical source of gravel for spawning habitat found farther downstream (Dunne and Dietrich 1978). Hence, the primary fluvial geomorphic function of the gorge was as a sediment transport reach between the upstream source areas and downstream depositional/alluvial areas. The gorge area (Reach 4) served primarily as a passage corridor for anadromous salmonids, providing rearing/holding habitat for juvenile and adult anadromous and resident fish alike. The lower portion of the middle Green River basin, below RM 45.0 (Reaches 4, 5, and 6), represents a gradient transition zone between sediment transport and deposition. Historically, much of the lower reach was braided and the stream meandered freely across the floodplain. The White River historically joined the Green River near RM 31 and contributed roughly 75 percent of the total sediment load to the lower basin. Sediment also originated from local landslides of glacially compacted valley floor material.

Peak stream flows occur during the winter and spring months as rainfall and snow melt runoff. Riparian wetlands bordered the channel along most of its length downstream of RM 45 (Reaches 4, 5, and 6), and episodic floods would cause the river to overflow its banks onto the floodplain. Adjacent wetlands and valley soils retained water during precipitation events and high flows, and subsequently supplemented the river's streamflow during summer and early fall low flow periods. Side channels were also present throughout much of the river in lower gradient reaches, providing rearing habitat for juvenile salmonids. Tributaries, both small and large, provided habitat for salmonids and other fish species.

Howard Hanson Dam has affected geomorphic processes and channel morphology in the Green River basin in a number of ways. Prevention of floods greater than 12,000 cfs (formerly equivalent to a 2-year return interval event) has reduced the river's ability to form and maintain off-channel habitats. The dam also traps LWD and sediment generated in the upper Green River basin. The interruption of downstream transport of LWD is believed to have reduced the amount of LWD in the middle Green River. The trapping of sediment has reduced delivery of coarse sediment to downstream reaches, resulting in bed armoring below the dam and the gradual loss of gravel and cobble-sized material important for anadromous fish spawning.

2.2 BIOLOGICAL RESOURCES

The historical fisheries habitat within the Green River basin is presumed to have been excellent for anadromous salmon and trout, resident trout, and other coldwater native species (USACE 1996). Anadromous fish species historically had access to the upper basin. However, adult anadromous fish access to the upper Green River was blocked by Tacoma's Headworks Diversion Dam at RM 61.0 (completed in 1912). Howard Hanson Dam at RM 64.5 (completed in 1962) represents an even more formidable barrier to upstream migration of fish.

Over 30 species of fish historically or currently inhabit the Green River, including up to nine anadromous salmonid species. Currently chinook, coho, chum, pink and sockeye salmon, steelhead and coastal cutthroat trout may be found at various times of the year in portions of the Green River. Native char (bull trout and/or Dolly Varden) have been observed to enter the lower Green/Duwamish River. Native resident salmonids include rainbow and cutthroat trout and mountain whitefish. Other native fish species are also present, including lamprey, minnows, sculpins, and suckers. Natural spawning anadromous fish have been recognized as a critical link in the aquatic food webs of the Pacific Northwest aquatic ecosystem.

Rearing in the ocean, adult anadromous salmon return to streams and when they die, their carcasses enrich the food web from primary producers to top carnivores. At the top of the food web, at least 22 species of wildlife, including black bear, mink, river otter, and bald eagle, feed on salmon carcasses (Cederholm et al. 1989). At the base of the food web, salmon carcasses provide a major amount of nitrogen to streamside vegetation, and large amounts of carbon and nitrogen to aquatic insects and other macroinvertebrates (Bilby et al. 1996). Some researchers suggest that a minimum escapement level for natural spawners may be needed to maintain the integrity of the aquatic food chain.

In addition to their importance to genetic diversity and biological cycles, local salmon and steelhead harvests in the Green/Duwamish basin provide for commercial, sport, subsistence, and cultural uses to people. In particular, Muckleshoot and Suquamish Tribal people have treaty fishing rights to Green River fish, which are important to their economic and cultural sustenance.

In response to the declining status of these valuable species, the U.S. Fish and Wildlife Service (USFWS) listed bull trout (64 FR 58910) and National Marine Fisheries Service (NMFS) listed Puget Sound chinook salmon as threatened (63 FR 11482) requiring protection under the ESA.

3. METHODS

3.1 MONITORING OVERVIEW

Establishing baseline conditions and monitoring changes in habitat conditions that result from restoration efforts and changing land and water management practices is fundamental to the recovery and conservation of salmonids. Monitoring is defined as a series of measurements that are repeated over time with the goal of detecting change (MacDonald et al. 1991). Monitoring differs from typical habitat assessments, which generally focus on making a single set of observations to characterize conditions at a given point in time. A critical element of monitoring is to develop specific project objectives and to identify monitoring parameters that are sensitive to the projects or programs to be implemented and that are quantifiable by direct measurement. Monitoring protocols must provide a statistically defensible method for evaluating and minimizing error (Johnson et al. 2001). To be useful in the context of a long term monitoring program, parameters to be tracked must be measurable with a known degree of precision and accuracy (Bauer and Ralph 1999). The specific objective of the reach scale monitoring described in this report is to establish baseline conditions from which future changes in habitat may be identified.

3.2 PROJECT APPROACH

3.2.1 Literature Review and Monitoring Workshop

The mainstem Green River Baseline Habitat Monitoring program was developed based on a review of commonly used habitat inventory protocols. Seven monitoring and assessment methodologies that are currently widely used throughout the Pacific Northwest were reviewed to guide the development of the middle Green River Reach scale Monitoring Program (Schuett-Hames et al. 1994; King County 1991; Moore et al. 1995; Johnston and Slaney 1996; Peterson and Wollrab 1998; Overton et al. 1997; May 1996). Each methodology is currently utilized by one or more agencies or organizations responsible for assessment and monitoring of aquatic habitat in the Pacific Northwest. Table 3-1 summarizes the general approach, habitat parameters measured, and strengths and weaknesses of each of the methodologies reviewed.

Table 3-1. Summary of habitat assessment and monitoring methods reviewed for applicability to the proposed mainstem physical habitat monitoring component of the Green River Habitat Restoration Evaluation Program.

HABITAT ASSESSMENT METHOD No. 1.
TFW Ambient Monitoring Program Manual

AUTHOR(s) DATE
Schuett-Hames, D., A. Pleus, L. Bullchild, and S. Hall 1994
(note: modules updated as stand alone in 1999)

PRIMARY OBJECTIVES
Repeatable survey methodology for detecting and documenting changes in both reach scale and site-specific habitat conditions over time.

APPROACH
Subsample randomly selected reaches

PHYSICAL
- Reference points
- Photographs
- Discharge
- Bankfull width
- Bankfull depth
- Canopy cover
- Habitat unit type
- Habitat unit dimensions
- Pool formative factor
- LWD count
- Key piece count
- LWD jams
- % fines
- Location and area of suitable spawning gravel
- Dominant substrate size
- Spawning gravel scour
- Riparian stand conditions
- LWD recruitment

CHEMICAL
- Temperature (continuous recorder or max-min)

BIOLOGICAL
- None

STRENGTHS AND WEAKNESSES OF APPROACH
Strengths:
- Set of linked or stand alone modules providing detailed survey methodology, equipment needs, field forms and data analysis information
- Inventory data is stratified by channel type
- Hierarchical survey design to support more or less detailed data collection as needed
- Quantifiable and repeatable measurement standards
- Provides information on developing statistically sound project approach
- Support system including data management, training and QA/QC
- Measurement parameters clearly specified to minimize sampler bias
- Identification of pools, spawning gravel availability independent of discharge
- Stream size considered when defining parameter criteria
- Provides framework for interpreting data (WFPB 1997)

Weaknesses:
- Designed for small streams (<20 m BFW); some measurements difficult to apply in larger rivers
- Time, labor and data intensive if applied as presented
- No biological component

Table 3-1. continued

HABITAT ASSESSMENT METHOD No. 2.
King County Stream Inventory Level 1, 2 and 3

AUTHOR(s) DATE
King County Building and Land Development 1991

PRIMARY OBJECTIVES
To collect data that may be used to evaluate instream habitat, riparian condition, and fish use prior to permitting activities which could alter fish habitat.

APPROACH
Sample entire length of non-randomly selected reach (project specific)

PHYSICAL

- Habitat unit type
- Habitat unit dimensions
- Average channel width (wetted and OHWM)
- Average channel depth (wetted and OHWM)
- Riparian community type
- Riparian community age
- Riparian buffer width
- Dominant and subdominant substrate
- Pool quality
- LWD (length, diameter, stability, type and condition)
- Cross-sections
- Pebble Count
- Species, size and position of riparian trees

CHEMICAL

- Temperature

BIOLOGICAL

- Fish presence (2-pass electrofishing)
- Documentation of habitat requirements and use
- Spawning surveys
- Macroinvertebrates (Level 3)

STRENGTHS AND WEAKNESSES OF APPROACH

Strengths:

- Standardized reporting form and data collection methods for measuring common attributes.
- Hierarchical survey design to support more or less detailed data collection as needed
- Includes biological component

Weaknesses:

- Designed for project level assessments, not long-term monitoring
- Designed for small streams (<20 m BFW); some methods difficult to apply in larger rivers
- Parameter definitions, measurement standards not clearly specified
- Identification of habitat units, spawning areas dependent on discharge
- Does not provide a methodological framework for integrating and interpreting data.
- No discussion of statistical validity of sampling design
- No existing centralized database
- No recommendations for training, QA/QC

Table 3-1. continued

HABITAT ASSESSMENT METHOD No. 3.
ODFW Stream Habitat Methods

AUTHOR(s) DATE
Moore, K., K. Jones, and J. Dambacher 1995

PRIMARY OBJECTIVES
To provide quantitative information on habitat condition for streams throughout Oregon.

APPROACH
Sub-sample every 10th habitat unit

PHYSICAL
- Channel type
- Gradient
- Photographs
- Discharge
- Riparian community type
- Habitat unit type
- Habitat unit dimensions
- Canopy cover
- Shade
- Bankfull width
- Bankfull depth
- Inter-terrace width
- Terrace height
- Substrate
- Boulder count
- Bank condition
- LWD count
- LWD complexity rating
- LWD type and volume

CHEMICAL
- Temperature

BIOLOGICAL
- None

STRENGTHS AND WEAKNESSES OF APPROACH
Strengths:
- Inventory data is stratified by channel type
- Provides semi-quantitative definitions of measured parameters
- Data compiled in centralized database
- Provides framework for interpreting data

Weaknesses:
- Designed for small streams (<20 m BFW); some methods difficult to apply in larger rivers
- Does not provide a methodological framework for integrating and interpreting data
- Identification of habitat units, spawning gravel availability independent of discharge
- Stream size considered when defining parameter criteria
- Measurement standards not clearly specified
- No discussion of statistical validity of sampling design
- Data intensive
- No recommendations for training, QA/QC

Table 3-1. continued

HABITAT ASSESSMENT METHOD No. 4.
BC Ministry of Environment, Land and Parks Watershed Restoration Program

AUTHOR(s) DATE
Johnston and Slaney 1996

PRIMARY OBJECTIVES
To provide information about fish distribution, population status, and the condition and capability of supporting habitats.

APPROACH
Subsample randomly selected habitat units

PHYSICAL
- Discharge
- Channel Type
- Evidence of recent disturbance
- Location of physical barriers
- Bankfull channel width and depth
- Wetted width and depth
- Maximum pool depth, riffle crest depth, residual depth
- Pool type
- Spawning gravel amount and type
- LWD-total
- LWD-functional
- Cover
- Riparian vegetation type
- Riparian structural stage
- Overhead Canopy closure
- Photographs

CHEMICAL
- Temperature (spot check during survey)
- Inorganic nutrients
- pH
- Turbidity

BIOLOGICAL
- Fish distribution and relative abundance

STRENGTHS AND WEAKNESSES OF APPROACH
Strengths:
- Inventory data is stratified by channel type
- Stream size considered when defining parameter criteria
- Standardized reporting form and data collection methods for measuring common attributes.
- Includes biological component and relevant WQ data
- Provides quantitative definition of parameters
- Provides framework for interpreting data

Weaknesses:
- Method intended for assessment and restoration prescription development, not monitoring
- Focuses on degraded habitats rather than representative sample
- No recommendations for training, QA/QC
- Biologic sampling not systematic
- Measurement standards not clearly specified
- Designed for small streams (<20 m BFW); some methods difficult to apply in larger rivers
- Data intensive
- No centralized database

Table 3-1. continued

HABITAT ASSESSMENT METHOD No. 5.
USFS Region 6 Stream Inventory

AUTHOR(s) DATE
Peterson, J. T., and S. P. Wollrab 1998

PRIMARY OBJECTIVES
Designed to monitor and refine land management plan standards and guidelines.

APPROACH
Subsample randomly selected habitat units

PHYSICAL

- Channel type
- Gradient
- Fish access
- Riparian width
- Riparian community type
- Habitat unit type
- Habitat unit dimensions
- LWD count
- Substrate
- Bankfull width
- Bankfull depth
- Floodprone width and depth
- Bank stability
- Discharge

CHEMICAL

- Temperature

BIOLOGICAL

- Fish
- Amphibians

STRENGTHS AND WEAKNESSES OF APPROACH

Strengths:

- Inventory data is stratified by channel type and watershed condition
- Provides quantitative delineation criteria
- Includes biological component

Weaknesses:

- No recommendations for training, QA/QC
- Weak linkage between biologic component and habitat/WQ
- Does not provide a methodological framework for integrating and interpreting data
- Designed for small streams (<20 m BFW); some methods difficult to apply in larger rivers
- No centralized database

Table 3-1. continued

HABITAT ASSESSMENT METHOD No. 6.
USFS R1/R4 (Northern/Inter-mountain Regions) Fish and Fish Habitat Standard Inventory Procedures

AUTHOR(s) DATE
Overton, C. K., S. P. Wollrab, B. C. Roberts, and M. A. Radko 1997

PRIMARY OBJECTIVES
To assess the direct, indirect, and cumulative effects of National Forest management activities on fish and fish habitat.

APPROACH
Complete inventory or subsample

PHYSICAL

- Rosgen channel type
- Gradient
- Riparian community
- Discharge
- Habitat unit type
- Habitat unit dimensions
- Pocket pool frequency
- Maximum pool depth
- Pool crest depth
- Step-pool total
- Percent surface fines
- Surface fines
- Substrate composition
- Bank stability
- Bank undercut
- Channel shape
- LWD count singles and rootwads
- LWD count aggregates
- LWD length and diameter
- Riparian Community Type
- Width/Depth ratio
- Photographs

CHEMICAL

- Water temperature (spot measurement during survey)
- Air temperature (spot measurement during survey)

BIOLOGICAL

- Fish (snorkel survey) species, age class

STRENGTHS AND WEAKNESSES OF APPROACH

Strengths:

- Inventory data is stratified by channel type and watershed condition
- Provides quantitative delineation criteria and photos for some habitat unit types
- Includes suggestions on designing a statistically valid subsampling program
- Includes biological component

Weaknesses:

- No recommendations for training, QA/QC
- Weak linkage between biologic component and habitat/WQ
- Does not provide a methodological framework for integrating and interpreting data
- Designed for small streams (<20 m BFW); some methods difficult to apply in larger rivers
- No centralized database

Table 3-1. continued

HABITAT ASSESSMENT METHOD No. 7.
Puget Sound Lowland Indices and Target Conditions

AUTHOR(s) DATE
May, C. W. 1996

PRIMARY OBJECTIVES
To determine cause-effect relationships between urbanization and stream quality and to develop a set of recommended stream quality indices and target conditions.

APPROACH
None recommended; original study used subsampling of non-randomly selected reaches

PHYSICAL

- Bank stability
- Substrate Quality (Pebble count and McNeil samples)
- Substrate Embeddedness
- Scour depth
- Large woody debris (LWD) frequency
- LWD volume
- Riparian buffer width
- Riparian cover type
- Riparian vegetation age
- Stream crossings/km
- Stormwater outfalls/km
- % Glide
- Qualitative Habitat Index (QHI)

CHEMICAL

- Intergravel dissolved oxygen (IGDO)/DO interchange
- Sediment, lead, and total zinc
- Stormflow event-mean concentration (EMC) total zinc
- Baseflow conductivity

BIOLOGICAL

- None

STRENGTHS AND WEAKNESSES OF APPROACH

Strengths:

- Original study data intensive; included discussion of which measured parameters represented most meaningful monitoring parameters
- Parameters for which criteria are recommended are quantitative
- Provides framework for interpreting data

Weaknesses:

- Analysis relevant to only one channel type
- Designed for small streams (<20 m BFW); some methods difficult to apply in larger rivers
- No biological component
- No centralized database

Acronyms

BFW:	bankfull width	QA/QC:	Quality Assurance/Quality Control
LWD:	large woody debris	TFW:	Timber, Fish, and Wildlife
ODFW:	Oregon Department of Fish and Wildlife	USFW:	United States Forest Service
OHWM:	ordinary high water mark	WQ:	water quality

Overall, a primary limitation of all methodologies reviewed is that each is designed for application in smaller streams (<20m bankfull width). In addition, six of the seven methodologies reviewed are designed primarily for use in habitat assessments rather than repeated monitoring surveys, thus most lack specific quality assurance and quality control guidelines. Monitoring requires that changes in habitat conditions be detectable with a known level of certainty. Because they are specifically designed for monitoring projects, consider potential sources of observer bias and error and incorporate a quality assurance and quality control program, the methodologies described in a set of manuals developed by Washington's Timber Fish and Wildlife (TFW) Committee were identified as the preferred methodology for use in long-term monitoring of the middle Green River. The procedures in the TFW manuals were modified for use in large rivers such as the Green River following discussions with biologists and geomorphologists currently involved in resource management and assessment in the Green River basin.

Reach scale monitoring is important for detecting the effects of programmatic mitigation and restoration measures (e.g., flow management or gravel supplementation). Reach scale monitoring is also needed to evaluate overall changes in habitat conditions resulting from integrated implementation of multiple projects. One consideration of potential reach scale monitoring methods is the need for measurement repeatability. Several researchers in the Pacific Northwest have evaluated the ability of trained observers to independently classify and measure instream habitat units (Ralph et al. 1994; Roper and Scarnecchia 1995; Pleus 1994). In an intensive investigation of the magnitude and sources of variability in repeat habitat surveys, Pleus (1994) noted that the only habitat type unit that was consistently identified by crews surveying the same reach was pools. Pleus (1994) further noted that differences in the measured surface area of individual pools ranged from 25 to over 40 percent even for crews that had received comparable training prior to completing surveys. The primary source of variability was differences in habitat unit boundary identification between crews. Thus, while reach scale information is necessary to document overall changes in habitat, conclusions should be limited to reach scale descriptors of pool habitats such as relative pool spacing (pool frequency).

In contrast, intensive mapping of shorter "reference reaches" can provide valuable information on the magnitude of process-driven changes in individual habitat units. Such surveys are ideal for detecting changes or differences in control and treatment reaches, but due to their limited area extent, may not be representative of macro-scale changes in habitat. Ideally, a basin-wide monitoring program should incorporate components of both approaches. Our recommendation is that the overall Green River monitoring program include both the reach scale monitoring program described here, as well as more intensive site-specific monitoring. Site-specific monitoring programs must be tailored to individual projects and is thus beyond the scope of this report.

The ability to identify the distribution and proportion of habitat types is likely to be influenced by the flow at which surveys are conducted. Use of parameters such as residual pool depth and bankfull width allows quantification of some habitat attributes independent of flow. Delineation of pool and riffle habitat units however, is influenced by flow condition. In order to reduce variability associated with flow, repeat surveys should be conducted at similar flows. In the Green River, flows are consistently between 250 and 400 cfs, as measured at the USGS gage at Auburn, between mid-August and late September. Scheduling surveys during this 6-week period should reduce measurement variability associated with seasonal changes in measurement parameters.

Feedback on the proposed approach was solicited at the Middle Green River Physical Habitat Monitoring Workshop convened in May 2001. Workshop attendees included representatives from NMFS, USFWS, WDFW, King County, MIT, USACE and Tacoma.

3.2.2 Stratification of Survey Area

Habitat surveys encompassed the entire study reach from Howard Hanson Dam at RM 64.5 to Auburn Narrows at RM 32. In order to balance the cost of monitoring against the need for comprehensive data on habitat conditions throughout the study area, reach scale monitoring focused on those specific parameters anticipated to be most responsive to the management programs (Section 3.2.3).

The study area was subdivided into six reaches to facilitate interpretation of monitoring data. For the purposes of the mainstem Green River physical habitat monitoring program, a reach is defined as a length of channel with relatively consistent channel morphology (gradient, confinement, planform, flow, bedform, substrate). Channel morphology is a useful tool for classifying streams and rivers because it: 1) dictates habitat conditions used by the various life-history stages of salmonid species (Beechie and Sibley 1997); 2) directly influences the productive capacity of each habitat type (Vannote et al. 1980; Naiman et al. 1992; Paustain et al. 1992); and 3) varies in terms of sensitivity and response to changes in inputs of water, wood and sediment from natural or anthropogenic disturbances or from restoration activities (Paustain et al. 1992; Montgomery and Buffington 1993; Rosgen 1997). Reaches are delineated as follows:

Reach 1: RM 64.5 (Howard Hanson Dam) to RM 61.0 (Tacoma Headworks)

Reach 2: RM 61.0 (Tacoma Headworks) to RM 57 (Kanasket State Park)

Reach 3: RM 57 (Kanasket State Park) to RM 45 (Flaming Geyser State Park)

Reach 4: RM 45 (Flaming Geyser State Park) to RM 40 (Newaukum Creek)

Reach 5: RM 40 (Newaukum Creek) to RM 38 (Loans Levee)

Reach 6: RM 38 (Loans Levee) to RM 32 (Auburn Narrows)

The monitoring program calls for surveying habitat throughout the mainstem Green River once before the AWSP and GD ERP (including all associated restoration and enhancement projects) are initiated and at specified intervals following implementation of the projects. Reach scale habitat surveys will be repeated at 5-year intervals until year 20, and at 10-year intervals until year 50. Data collected in 2001 represents baseline, pre-project conditions. The higher frequency of monitoring during the first 20 years occurs because habitat is expected to be most responsive to the initial implementation. Continued monitoring at a reduced intensity will facilitate adaptive management and document changes in parameters (e.g., riparian zones) that are expected to respond more slowly.

3.2.3 Key Monitoring Parameters

A set of key parameters to be measured repeatedly as part of the reach scale habitat monitoring program were identified based on the literature review. Key parameters represent habitat attributes that: 1) are expected to be most responsive to management actions or restoration and mitigation projects and 2) can be accurately quantified with minimal measurement error or observer bias.

Key parameters to be quantitatively measured throughout the survey area during reach scale habitat monitoring include bankfull width, canopy cover, pool habitat unit location and dimensions, LWD, and riffle particle size distributions. Possible impediments to the upstream migration of salmonids were identified, mapped, and described quantitatively. Impediments to upstream migration included waterfalls or bedrock steps, cascades with a gradient greater than 12 percent, and shallow riffles where there are no continuous flow paths with a depth greater than 30 cm. Definitions and procedures used to measure attributes of each of these key parameters are described below.

Workshop participants and the USACE also expressed a desire to identify gravel storage sites and quantify the amount of gravel currently in storage. Identification of potential gravel storage sites is necessarily a two-stage process. Existing and potential gravel storage sites were identified and mapped during the habitat surveys. Follow-up surveys are required to quantify the amount of gravel stored in selected sites.

Bankfull Width

Bankfull width is the distance between the bankfull channel edges, which are defined by the abrupt changes in bank morphology, composition and vegetation (Figure 3-1). Bankfull channel width was measured to the nearest 2-meters approximately every 300 meters using a laser rangefinder. The location of bankfull width transects was recorded using GPS and marked on laminated copies of aerial photographs covering the river corridor. Photographs were taken looking downstream at each bankfull width transect.

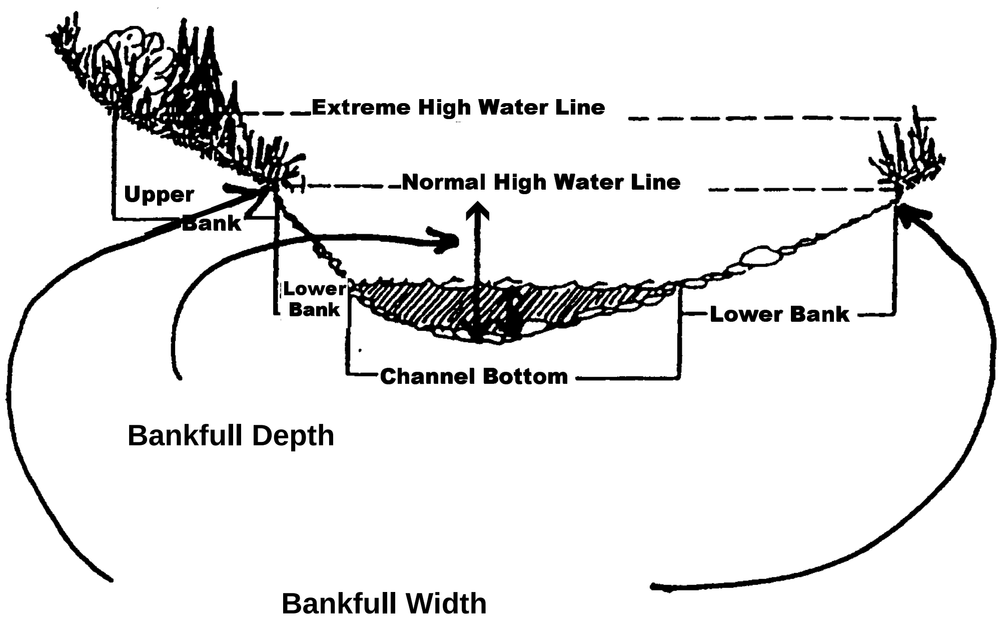


Figure 3-1. Identification of bankfull width, bankfull depth and lower bank (from Pfunkuch 1975).

Canopy Cover

Canopy cover refers to the amount of area over the stream channel that is shaded by riparian trees or shrubs. At each bankfull width transect a spherical densiometer was used to assess canopy cover. Canopy cover data was collected in the center of the wetted channel.

Habitat Units

Habitat units represent short reaches of channel with unique depth, velocity and morphologic characteristics. At the request of workshop participants, all habitat units identified during the surveys were delineated on the aerial photo basemaps. However, based on the results of the literature review documenting major difficulties in the repeatability and accuracy of measurements conducted in habitat types other than pools, quantitative measurements were collected only in pool habitat units. Habitat units were classified according to a modified version of the hierarchical system developed by Hawkins et al. (1993). This system recognizes two basic classes of habitat: fast water habitat and slow water habitats. For this survey, those basic habitat classes were further broken down into seven habitat types (Figure 3-2).

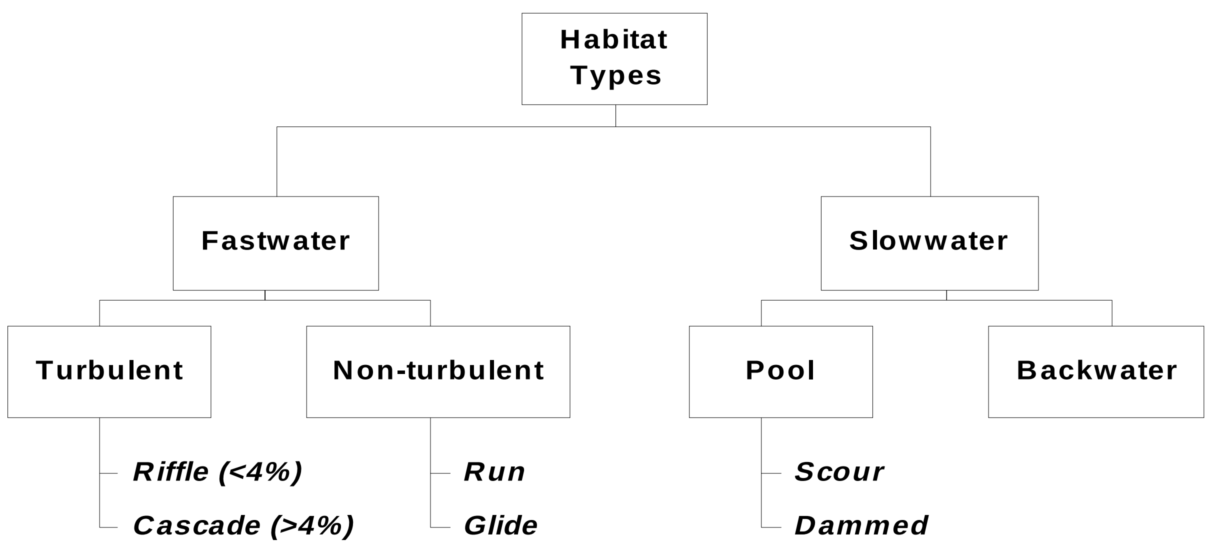


Figure 3-2. Habitat type classification system utilized for middle Green River baseline mainstem habitat monitoring, 2001 (after Hawkins et al. 1993).

Slow water habitat types consist of pools and backwaters. Pool habitats are areas where water is impounded within a closed topographical depression. Such depressions commonly form where water has scoured out a concavity in the channel bed or where the channel has been dammed. Pool habitats were further stratified as scour or dammed and by their formative characteristics (Figure 3-2). Backwater habitats are areas of low or no velocity separated from the main flow hydraulically and physically.

Fast water habitat types generally have a velocity that is greater than 0.3 meters per second. Fast water habitat types are further characterized as turbulent or non-turbulent. Fastwater habitats exhibiting surface turbulence include cascades and riffles. Turbulent, fast water habitats with a water surface slope greater than 4 percent are classified as cascades. Turbulent fast water habitats with a water surface slope less than 4 percent are classified as riffles.

Fast water habitats that do not exhibit surface turbulence often appear pool-like because of their depth and lack of surface agitation. However, unlike pools, non-turbulent fastwater habitats do not exhibit a well-developed depression. Non-turbulent habitat units that are deep and swift with a well-defined thalweg are classified as runs. Non-turbulent fastwater habitats with low to moderate velocity, a uniform bed, and no defined thalweg are classified as glides.

Pools

Pool habitat units are bounded by an upstream pool head and a downstream riffle crest (Figure 3-3). To be classified as a pool habitat unit, the concave depressional area was required to occupy at least 50 percent of the wetted channel width and have a residual depth greater than 1 meter.[2] Smaller pool units were noted on the map and described in field notes, but not measured. Quantitative measurements were collected at each pool habitat unit. The up and downstream end of each pool habitat unit were located using GPS (where possible). Pool length and width were measured using a laser rangefinder. The length of each pool was measured along the center of the wetted channel. Three to six width measurements per pool perpendicular to the pool centerline were obtained depending on the pool length and complexity. The maximum pool depth was measured using a graduated wading rod or a 2-pound weight attached to a surveyors tape. Riffle crest depths were measured to the nearest 0.1 meter graduated wading rod.

[2] The minimum residual depth of 1 meter was selected because previous habitat data collected on the mainstem Green River indicate that the majority of habitat units classified as pools are deeper than 1 meter under late summer low flow conditions (Malcom 2001).

The factor responsible for forming each pool was recorded. Pool forming factors include both natural and man-made features. Natural pool-forming factors include LWD, bedrock, boulders, bedforms or the confluence with a tributary or side channel. Pools formed by bedforms include those formed by bed steps (a bed step is a transverse rib of boulders or cobbles that extends across the entire channel) and those formed by the hydraulics associated with a riffle/pool sequence. Pools are defined as being formed by boulders where single large individual boulders or groups of boulders result in local scour. Man-made pools include those formed by dams, culverts, bridge abutments or constructed and anchored LWD or engineered log jams (ELJs). In addition to the pool forming factor, the pool type was also recorded. Pool types include scour or dammed.

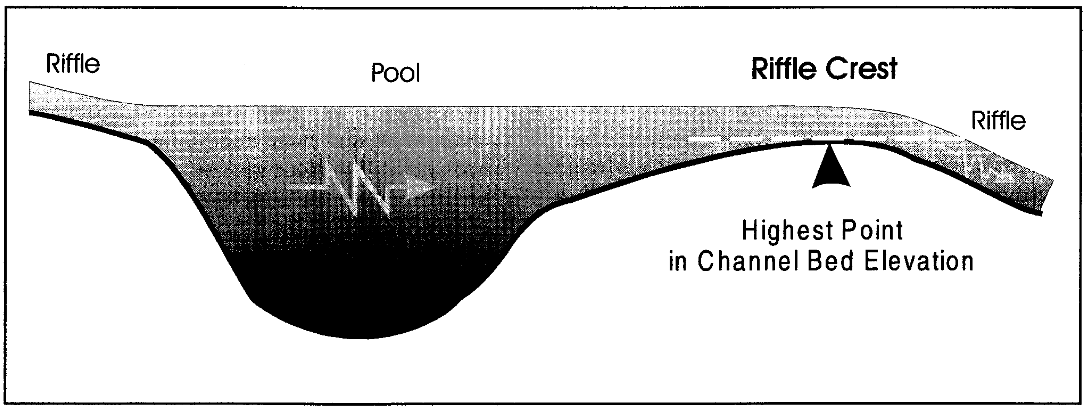


Figure 3-3. Upstream and downstream boundaries used when defining a pool habitat unit (from Pleus et al. 1999).

Large Woody Debris

Large woody debris were surveyed according to a modified version of the Level 1 protocol[3] outlined in the TFW Method Manual for Large Woody Debris Survey (Schuett-Hames et al. 1999a). Only wood located wholly or partially within zone 1 (wetted channel) or zone 2 (bankfull channel) was counted (Figure 3-4). A piece of wood must be at least 10 cm in diameter and 3.65 meters long to count as a piece of LWD, and a debris jam must contain 10

[3] The TFW manual (Schuett-Hames et al. 1999) describes two levels of survey intensity. Level I surveys are appropriate for extensive reach-scale efforts. Intensive Level II surveys are most appropriate for short survey segments and best suited for site-specific monitoring.

pieces of LWD to count as a debris jam. Debris jams were categorized by size as follows: 10 to 50 pieces, small; 50 to 100 pieces, medium; and greater than 100 pieces, large. The location of LWD jams (> 100 pieces) was recorded using GPS (where possible) and marked on the aerial photograph based on readily recognizable landmarks.

To ease data collection efforts, individual pieces with a diameter smaller than 30.5 cm and a length of less than 9.1 meters were counted only when they occurred as part of a qualifying debris jam. Individual pieces this size that are not incorporated into a jam are unlikely to remain stable in the channel or influence channel morphology. Single pieces of LWD were tallied by size classes as follows: diameter 30.5 to 50 cm, medium log; diameter greater than or equal to 50 cm but less than 85 cm, large log; diameter greater than or equal to 85 cm, key piece.[4] The count of wood further noted whether individual pieces of wood that are not part of a debris jam were cut and must whether they had an attached rootball or not. To qualify as a rootball, the size of the rootmass must be a minimum of 1.2 meters in diameter. Criteria used to identify qualifying individual pieces of LWD are depicted in Figure 3-4.

Riffle Substrate

Riffles represent locations within the channel where bedload is stored between high flow events. They are generally composed of well-sorted material that is representative of the size of sediments transported through a given stream reach. As such, they represent they represent good locations to obtain a sample of sediment when the goal is to characterize bedload composition.

Riffle substrate was characterized by conducting five pebble counts per reach in randomly selected riffle habitat units (Wolman 1954). The b-axis of 100 randomly selected particles was measured for each pebble count. Where the river was wadable, pebble count surveys traversed the entire active channel. If the river was not wadable, pebble counts extended from the bankfull channel margin to a point where the water depth exceeded approximately 2-feet. The location of sites where pebble counts were conducted was recorded using GPS (where possible) and marked on the aerial photograph based on readily recognized landmarks.

Potential Migration Barriers

Areas where the upstream migration of salmonids may be delayed in the mainstem Green River include shallow riffles or steep cascades. The location of riffles with a maximum depth of less

[4] Perkins (1999) estimated that the minimum size of a key piece of LWD in the mainstem Green River is 85 cm in diameter and at least 10 meters long.

than 30 cm across the entire wetted channel at late summer low flow conditions was recorded using GPS (if possible) or marked on a photograph. The length of the shallow section of the riffle was measured using a stadia rod or laser rangefinder. The gradient of the shallow section of riffle was measured using a clinometer and stadia rod.

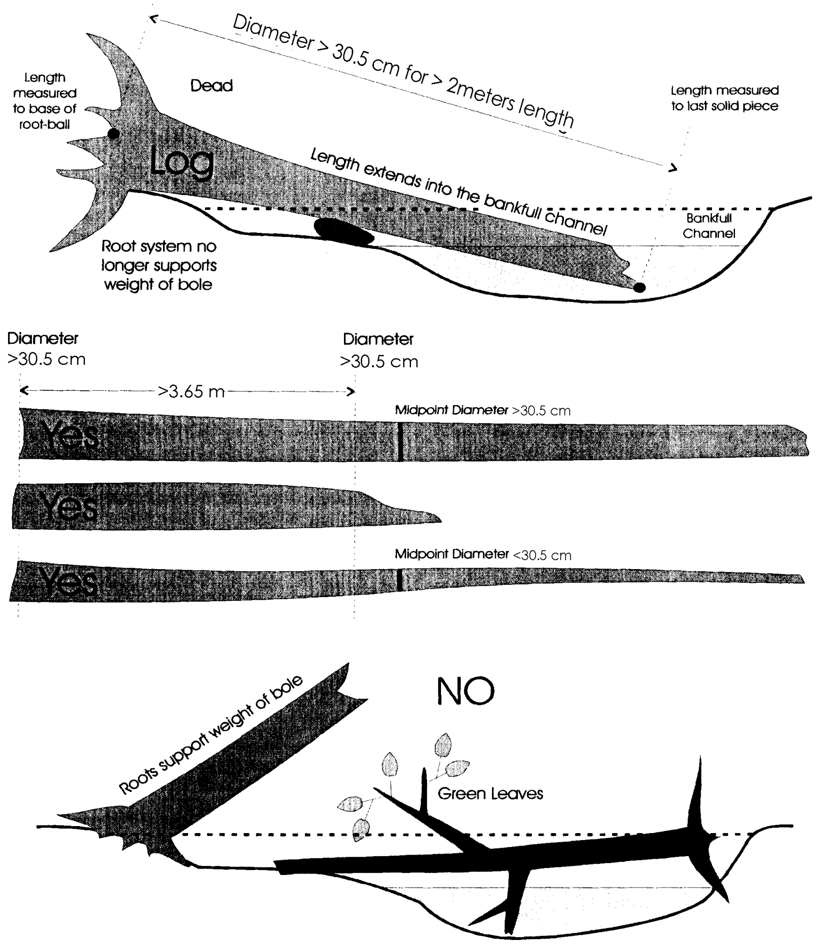


Figure 3-4. Criteria for identification of individual log utilized in 2001 baseline monitoring surveys of the mainstem middle Green River, King County, Washington (after Schuett-Hames et al. 1999a).

Cascades or bedrock chutes with a maximum depth of less than 30 cm, a drop of more than 1-meter, or a water surface slope greater than 12 percent were also identified and measured as described above. Photographs were taken of each site where potential passage concerns were identified.

Gravel Storage Sites

Following initiation of the surveys, stakeholders requested that gravel deposits and potential storage sites in Reaches 1-3 be identified. Existing and potential gravel storage sites were identified and noted in field notes and on the aerial photo base maps. Existing gravel storage sites included gravel bars, pool tailouts and channel margin deposits. Potential gravel storage sites included pool tailouts and, in high gradient reaches including Reaches 1, 2, and 3, areas of divergent flow and low gradient riffles with numerous flow obstructions. The results of these observations are reported in Appendix D.

Quantification of existing and potential gravel storage is a two stage process that will necessarily combine elements of reach scale and more intensive site-specific monitoring. The location of all existing and potential gravel storage sites was recorded during the 2001 habitat surveys. Detailed maps of the substrate and selected sites should be constructed as part of site-specific monitoring efforts following the procedures outlined in the TFW Salmonid Spawning Availability Manual (Schuett-Hames et al. 1999b).

3.2.4 Quality Assurance/Quality Control

The quality assurance quality control (QA/QC) program is a critical part of a successful monitoring project. For the mainstem Green River Habitat Monitoring Program, QA/QC measures were implemented at a variety of levels.

Equipment Calibration and Gear

Field equipment used to measure habitat attributes was checked for damage and calibrated at the beginning and end of field work. Laser rangefinders were checked by sighting to a clear, stationary target then measuring the distance to that target with a metric surveyors tape. Wading rods and depth sounders were checked by comparing them to metric surveyors tapes.

Equipment and wading gear used to survey each reach were documented at the start of the survey. Records of the gear and equipment used to conduct surveys are important to ensure the repeatability of future surveys.

Categorical Data Collection

Specific definitions of all categorical data (habitat types, LWD size classes, bankfull width indicators) were reviewed by all survey team personnel prior to initiating field work. Team leaders worked together for the first five days of the surveys to standardize categorical data calls.

Repeat Surveys

Repeat surveys of two approximately 1-mile long segments were conducted within two weeks of the original survey to provide information on data precision and accuracy. Each reach re-surveyed contained at least three pool habitat units and one pebble count site. Repeat surveys were performed by a different crew than the original survey.

LWD Calibration

In the case of LWD, team leaders each estimated then measured at least the first 50 pieces of LWD encountered, with the goal of reducing estimator error to less than 10 percent. Estimation and measurement continued until a satisfactory calibration rate was achieved.

Data Entry Check

All data forms, field books and calculations were reviewed for errors and discrepancies within three weeks following the end of the surveys. Questionable data points were corrected or eliminated from the analysis population.

Data was entered into EXCEL spreadsheets then cross-checked against the original field forms by a second person who had also been involved in the field work. The date and initials of the individual responsible for the original data entry and the data review were recorded both on the original field notes and in the electronic files.

3.3 DATA ANALYSIS

Data analyses were conducted using MS EXCEL and ArcInfo and ArcView GIS tools. Simple statistics and charts describing habitat characteristics generated for each reach include:

- average bankfull width, wetted width and canopy cover;
- pool spacing;

- factors responsible for pool formation (number and percent of pools formed by each factor identified);
- frequency of LWD and key pieces,
- percent of pools formed by LWD; and
- riffle substrate particle size distributions, D_{16}, D_{50} and D_{84}.

A GIS basemap was constructed depicting habitat units, LWD jams, potential barriers and the location of pebble count sites. Individual pieces of LWD were not recorded on GIS maps. Habitat units were digitized onto a set of 1998 black and white digital orthophotos with a 3-foot pixel size obtained from the Washington Department of Natural Resources. Data for each individual pool and summary tables for each reach were linked to the habitat unit map using lookup tables related by a unique identifier. Habitat unit boundaries were visually identified on the photobase maps and may not have the same dimensions as field measurements. The GIS maps should not be used to estimate habitat unit area.

4. RESULTS

The gradient of the Green River within the study area ranges from approximately 0.9 percent near HHD to 0.25 percent near Auburn (Figure 4-1). The valley form varies by reach (Figure 4-2). Upstream of RM 61, the river is confined between steep sideslopes formed of the resistant volcanic bedrock of the Cascade Mountains. Between RM 57 and 61, the river flows through a moderately wide, north trending valley cut prior to the most recent glaciation (Dunne and Dietrich 1978). The valley here is broader than in either the upstream or downstream reaches, but the river, which formerly meandered through this section, has been straightened, thus the gradient remains high. At RM 55, the river again steepens and enters a narrow gorge cut through relatively erodible bedrock. The downstream end of the river, from RM 45 to RM 32 flows through a wide alluvial valley cut into glacial drift deposits that form steep, unstable bluffs on either side of the valley.

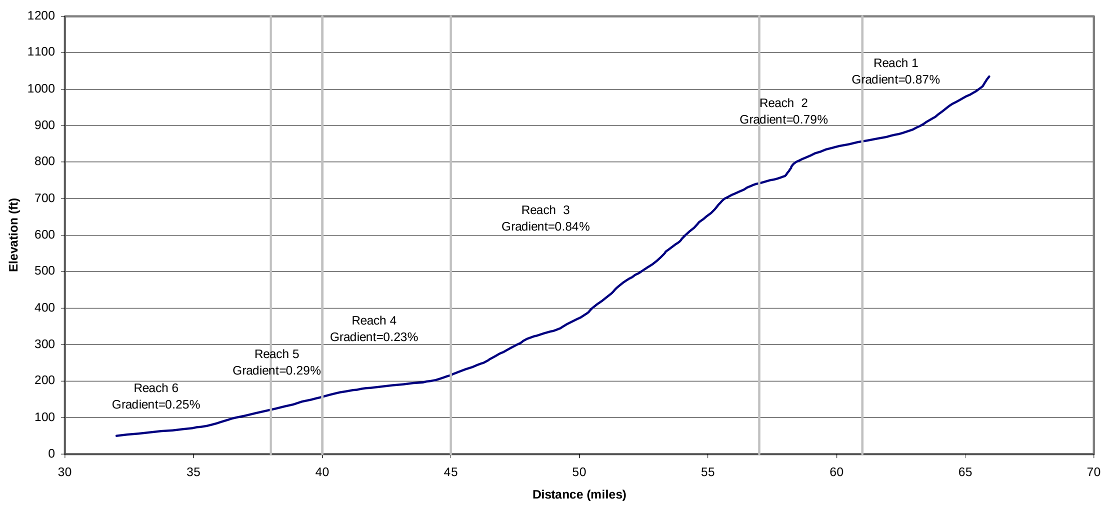


Figure 4-1. Profile of the mainstem middle Green River between River Mile 32 and River Mile 64.5.

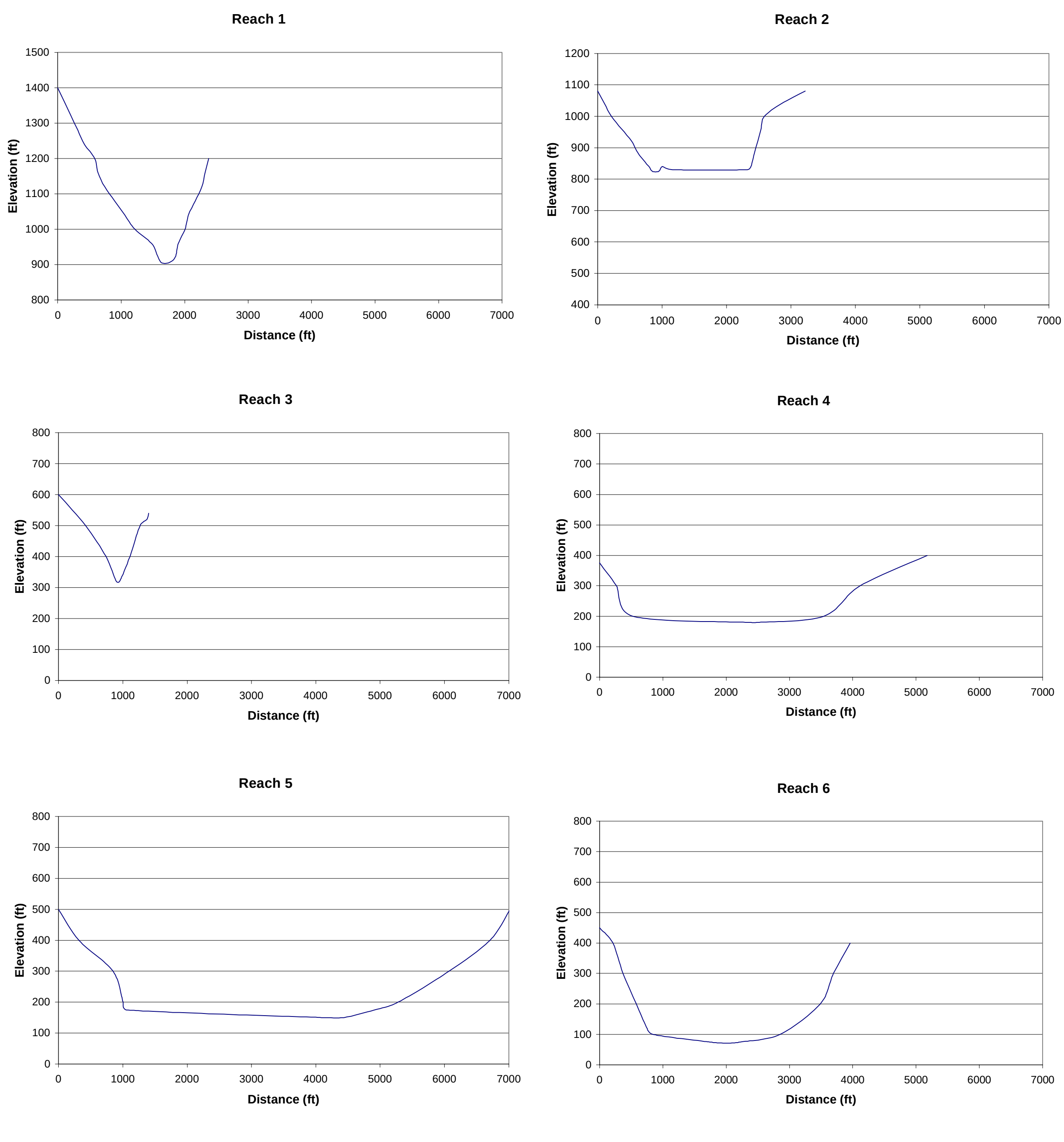


Figure 4-2. Valley profiles for Reaches 1 through 6 as designated for the 2001 mainstem middle Green River baseline habitat monitoring.

Habitat surveys were conducted on August 13 through August 24, August 29 and September 10 through September 13. A large storm event on August 22 and August 24 raised flows above conditions representative of summer baseflows and necessitated a delay in completion of the surveys. The following sections provide a reach by reach summary of habitat forming processes and existing channel conditions based on the results of the baseline habitat monitoring surveys. EXCEL spreadsheets containing the complete habitat survey database are contained in an appendix to this report.

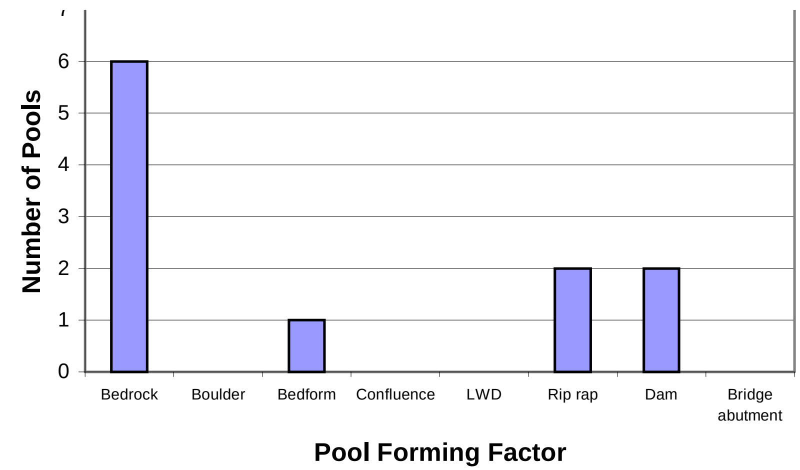
4.1 REACH 1

Reach 1 is confined between steep, mountainous side slopes. Reach 1 is further constrained along much of its length by the access road to HHD and the upper watershed. The sinuosity (channel length/valley length) is 1.0. The channel alternates between pool, riffle and cascade bedforms. The mean bankfull channel width is 33 m, while mean wetted width is 27 m. Surveys of Reach 1 were conducted on August 24 and September 10, 2001. Outflows from HHD on these survey dates were 223 cfs and 231 cfs, respectively.

Summary statistics for habitat data collected in Reach 1 are presented in Figure 4-3. The dominant habitat type is riffle, comprising almost 60 percent of the habitat area (Figure 4-4). The next most common habitat was pool. Eleven pools were identified in Reach 1, resulting in a pool spacing of 13 channel widths per pool (Figure 4-3). Pools comprised approximately 24 percent of the habitat area. The majority of pools encountered in Reach 1 were formed by bedrock. Other pool forming factors noted in Reach 1 were bedforms, riprap and dams. A large scour pool has formed below the outflow of HHD. Turbulence and high velocity precluded safe measurement of pool attributes at that site. A large, low velocity dammed pool has formed behind the Headworks Diversion Dam. Construction at that site prevented measurement of pool attributes.

Nineteen individual pieces of pieces of large woody debris and rootwads, including one key-sized piece, were identified in Reach 1 (Table 4-1). Of the individual pieces of LWD identified, less than 50 percent were located within Zone 1 (wetted channel). Where LWD did intersect the wetted channel, only the extreme ends were interacting with the low flow channel (Figure 4-5). No LWD jams were identified in Reach 1.

Summary Statistics	
Location	RM 61-RM 64.5
Channel Type	Large Contained
Confinement	Confined
Length	5,632
Gradient	0.90%
Outflow from HHD	223-231 cfs
Average bankfull width	33 m
Average wetted width	27 m
Pool Frequency (CW/pool)	13
Percent pool by length	20%
Percent pool by area	16%
Average residual pool depth	2.7 m
Dominant pool forming factor	Bedrock
Pools formed by LWD	0%
Total LWD	18
LWD Frequency (Pieces/CW)	0.1
LWD/mile	5.1
Cut LWD	6%
Total # Key	1
Key Frequency	0.01
Total # Jams	0
% Small jams	NA
% Medium jams	NA
% Large jams	NA
D_{16}	59 mm
D_{50}	158 mm
D_{84}	348 mm
Shade	15%



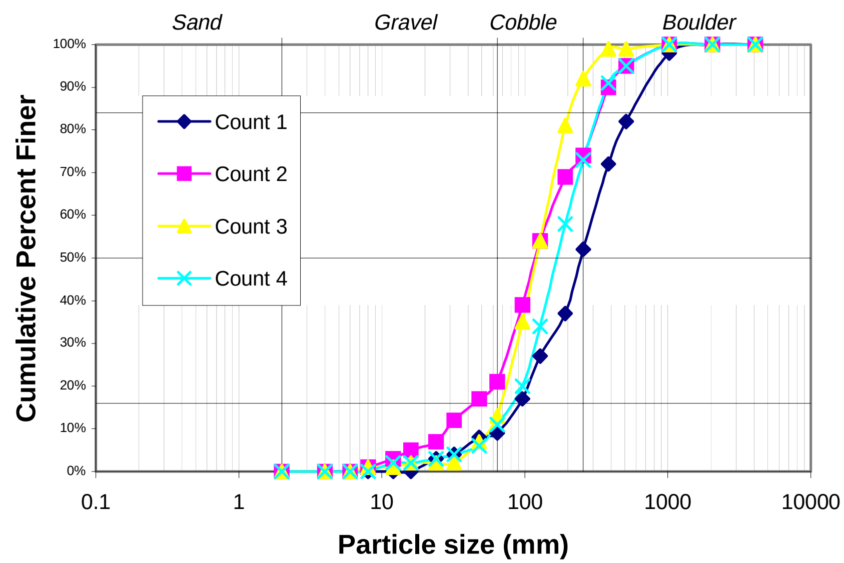


Figure 4-3. Summary data for 2001 Mainstem Green River Baseline Habitat Surveys, Reach 1.

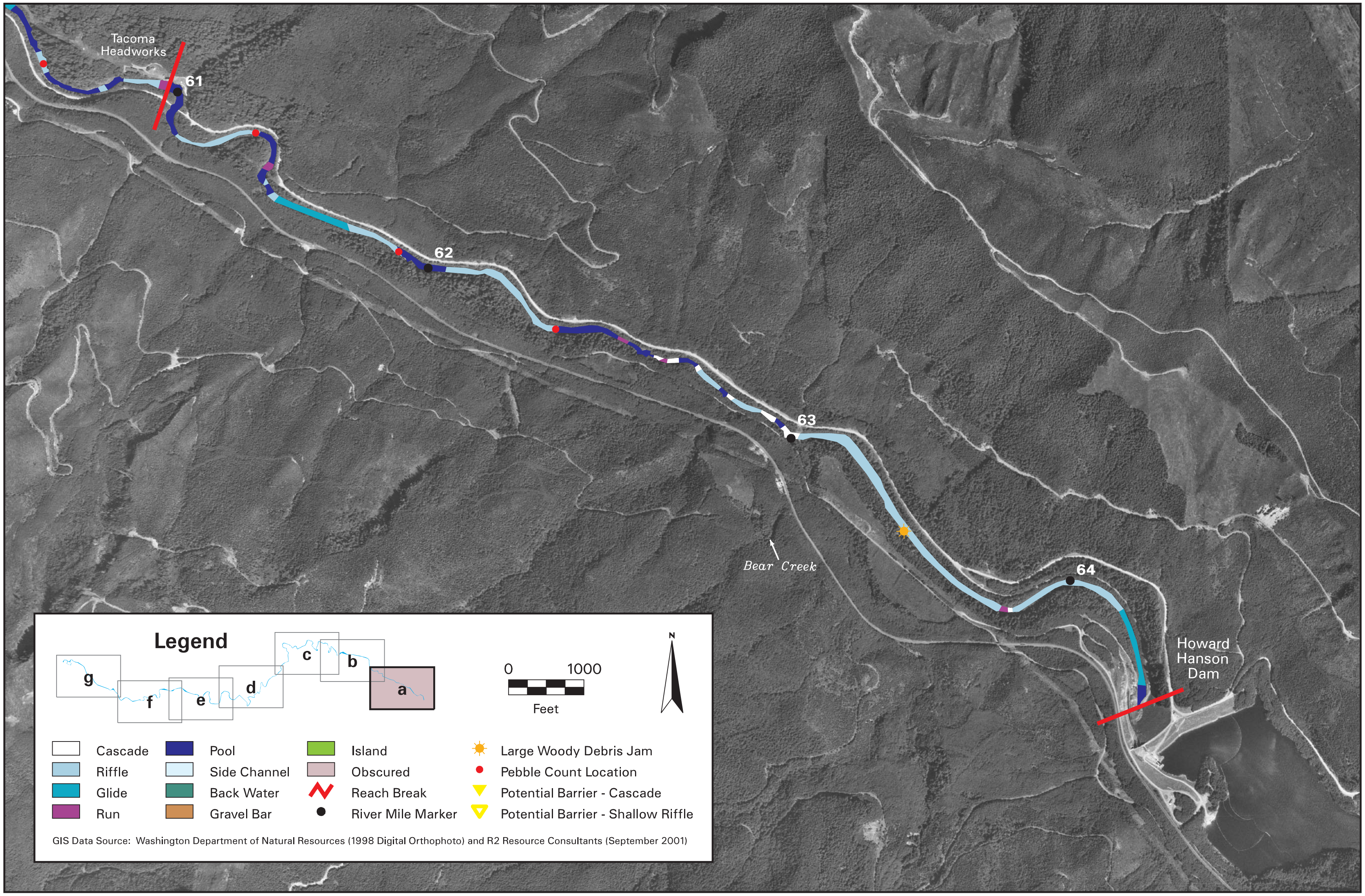


Figure 4-4. Middle Green River physical habitat Reach 1 (Map a).

Table 4-1. Zone and type of large woody debris in Reach 1, mainstem Green River habitat surveys, King County, Washington, 2001.

Size	Zone 1	Zone 2	Total	Cut
Log-Medium	4	8	13	0
Log-Medium with Rootwad	3	1	4	0
Log-Large	0	0	0	0
Log-Large with Rootwad	0	0	0	0
Key Piece	2	0	2	0
Rootwad	0	0	0	NA
Small Jam	0	0	0	0
Medium Jam	0	0	0	0
Large Jam	0	0	0	0

Figure 4-5. Typical orientation of LWD in middle Green River Reach 1.

Substrate in Reach 1 is primarily boulders. Pebble counts were conducted in riffle habitat types that tended to be composed of smaller material than was observed in steeper cascades and pools. The mean D_{50} particle size of all five pebble counts was 158 mm, and the D_{50} ranged from 141 mm to 246 mm (Figure 4-3). Boulders larger than 256 mm comprised from 8 to 48 percent of individual counts.

No natural potential passage impediments were identified in Reach 1. However, anadromous fish are currently prevented from accessing Reach 1 by the Tacoma Headworks Diversion Dam located at RM 61.

4.2 REACH 2

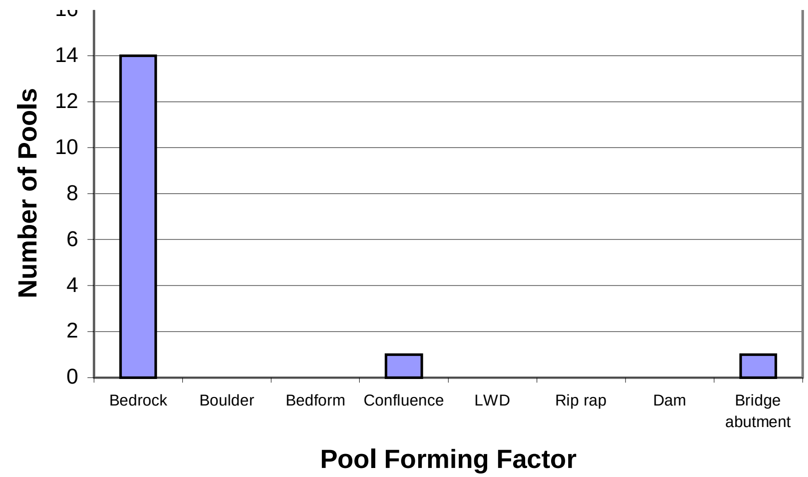
Reach 2 is former unconfined floodplain channel that occupies a one-half mile wide valley bottom located just upstream of the Green River gorge. Two large meanders (now side channels known as Signani slough and Brunner slough) were cut off early in the 20th century around the time the Burlington Northern Sante Fe Railroad and Tacoma's Headworks Diversion Dam were being constructed. These off channel habitats will be reconnected to the mainstem as part of the AWSP and GD ERP. Prior to straightening the channel sinuosity was as high as 1.27, but currently the sinuosity is 1.08. Straightening of the channel increased the gradient of this reach from about 0.5 percent to its current 0.8 percent (Figure 4-1). The channel currently alternates between, pool, riffle and cascade bedforms. The mean bankfull channel width is 41 m, while mean wetted width is 32 m. Surveys of Reach 2 were conducted from 11 to 13 September 2001. The flow at Palmer during the survey of Reach 2 was 133 cfs. This flow represents typical summer low flow conditions.

Summary statistics for habitat data collected in Reach 2 are presented in Figure 4-6. The dominant habitat type is riffle, which comprises more than half of the habitat area (Figure 4-7). Pools are the next most common habitat type, comprising approximately 20 percent of the reach by length. The only potential passage impediment identified in Reach 2 was a bedrock ledge with a drop of approximately 1 meter located near RM 58 (Figure 4-8). Several adult chinook were observed spawning in Reach 2 upstream of this location during the habitat surveys, following a high flow event that occurred August 22 and 23, 2001.

Sixteen pools were identified in Reach 2, resulting in a pool spacing of 11 channel widths per pool (Figure 4-6). Pools comprised approximately 27 percent of the total habitat area. The majority of pools encountered in Reach 2 were formed by bedrock. Other pool forming factors noted in Reach 2 were confluence sites where side channel flow rejoined the main flow, and a set of old bridge abutments located just downstream of RM 59.

Thirty-six individual pieces of pieces of large woody debris and rootwads, including two key-sized pieces, were identified in Reach 2 (Table 4-2). Of the individual pieces of LWD identified,

Summary Statistics	
Location	RM 57-RM 61
Channel Type	Pool-Riffle
Confinement	Unconfined
Length	6,437m
Gradient	0.80%
Flow at Palmer	133 cfs
Average bankfull width	41 m
Average wetted width	32 m
Pool Frequency (CW/pool)	11
Percent pool by length	26%
Percent pool by area	20%
Average residual pool depth	3.0 m
Dominant pool forming factor	Bedrock
Pools formed by LWD	0%
Total LWD	36
LWD Frequency (Pieces/CW)	0.2
LWD/mile	9.0
Cut LWD	0%
Total # Key	2
Key Frequency	0.01
Total # Jams	0
% Small jams	NA
% Medium jams	NA
% Large jams	NA
D_{16}	25 mm
D_{50}	137 mm
D_{84}	317 mm
Shade	17%



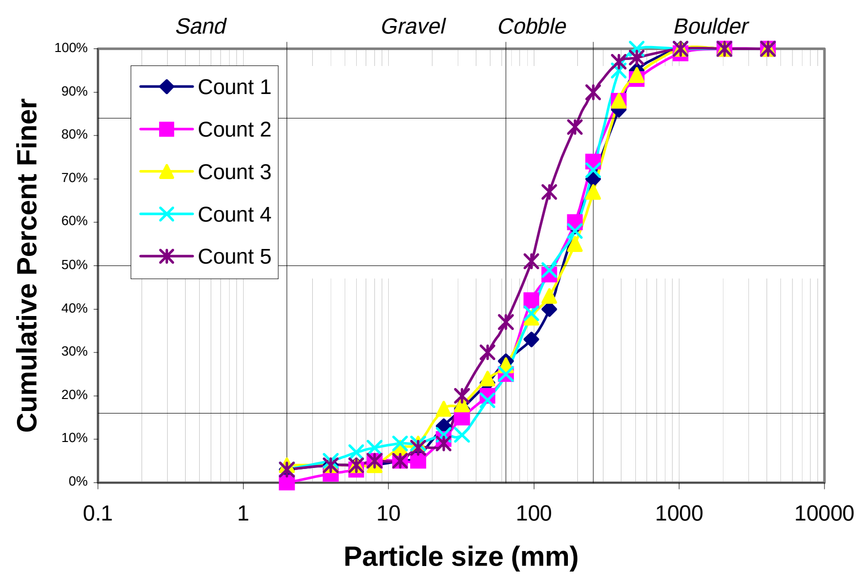


Figure 4-6. Summary data for 2001 Mainstem Green River Baseline Habitat Surveys, Reach 2.

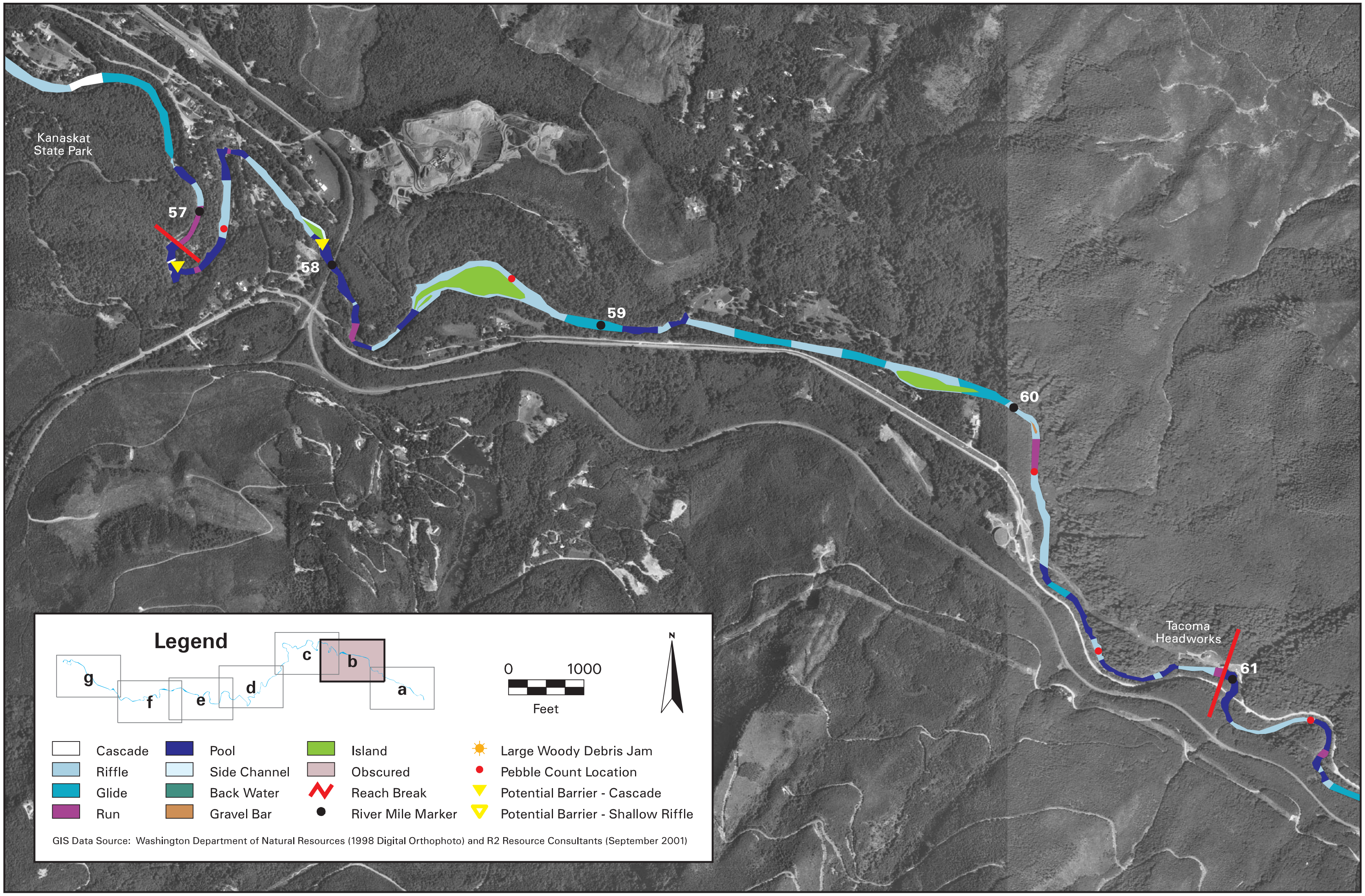


Figure 4-7. Middle Green River physical habitat Reach 2 (Map b).

Figure 4-8. Bedrock ledge near RM 58, Reach 2, mainstem middle Green River, King County, Washington, September 12, 2001.

Table 4-2. Zone and type of large woody debris in Reach 2, mainstem Green River habitat surveys, King County, Washington, 2001.

Zone	1	2	Total	Cut
Log-Medium	7	6	13	0
Log-Medium with Rootwad	3	0	3	0
Log-Large	8	4	12	0
Log-Large with Rootwad	2	2	4	0
Key Piece	0	2	2	0
Rootwad	1	1	2	NA
Small Jam	0	0	0	0
Medium Jam	0	0	0	0
Large Jam	0	0	0	0

64 percent were located within Zone 1; however, in most cases only the extreme ends were interacting with the low flow channel. No LWD jams were identified in Reach 2.

Substrate in Reach 2 is primarily boulders. Pebble counts were conducted in riffle habitat types that tended to be composed of smaller material than was observed in steeper cascades and pools. The mean D_{50} particle size of all five pebble counts was 137 mm, and the D_{50} ranged from 93 mm to 162 mm (Figure 4-6). Boulders larger than 256 mm comprised from 10 to 33 percent of individual pebble counts.

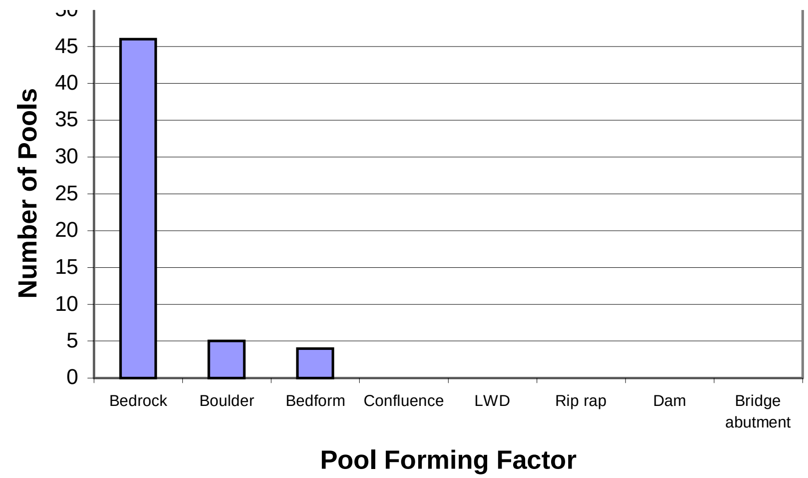
Gravel storage in Reach 2 is currently low. Channel margin and point bars are rare and small. Gravel and cobble tailout deposits were noted in only three of the 16 pools. Several long, gravel and cobble riffles were noted in the lower ½ mile of Reach 2 where pebble count five was performed (Figure 4-7). A number of low gradient riffles currently composed of large cobble and boulders were noted between RM 59 and RM 61. These sites represent potential future gravel storage sites.

4.3 REACH 3

Reach 3 occupies a deep bedrock canyon known as the Green River gorge. The channel alternates between pool, riffle, and cascade bedforms. The mean bankfull channel width is 39 m, while mean wetted width is 28 m. Reach 3 has a gradient of 0.8 percent (Figure 4-1) and a sinuosity of 1.0. Surveys of Reach 3 were conducted from 13 to 17 August and 24 August 2001. Flows at Palmer during the survey of Reach 3 ranged from 109 cfs to 131 cfs. These flows represent typical summer low flow conditions.

Summary statistics for habitat data collected in Reach 3 are presented in Figure 4-9. The dominant habitat type is riffle, which comprises 41 percent of the habitat by area (Figure 4-10a and b). The next most common habitat type is pool, comprising almost 25 percent of the habitat area. Cascades and runs are also common. Several steep cascades and bedrock shelves with a drop greater than 1 meter were identified in Reach 3 (Figure 4-11). It is unknown whether these sites represent impediments to the upstream migration of fish at low flows. Adult chinook, coho salmon, and steelhead trout are routinely observed at the base of Tacoma’s Headworks Diversion Dam at RM 61 indicating that they can pass these barriers at some flows. Several adult chinook were observed spawning upstream of these barriers following the August 22 and 23 storm event, during which flows at the Palmer gage reached 133 cfs and flows at the Auburn gage exceeded 400 cfs.

Summary Statistics	
Location	RM 45-57
Channel Type	Large Contained
Confinement	Confined
Length	19,311 m
Gradient	0.80%
Flow at Palmer	109-131cfs
Average bankfull width	39 m
Average wetted width	28 m
Pool Frequency (CW/pool)	9
Percent pool by length	25%
Percent pool by area	21%
Average residual pool depth	2.8 m
Dominant pool forming factor	Bedrock
Pools formed by LWD	0%
Total LWD	164
LWD Frequency (Pieces/CW)	0.3
LWD/mile	13.7
Cut LWD	7%
Total # Key	11
Key Frequency	0.02
Total # Jams	8
% Small jams	100%
% Medium jams	0
% Large jams	0
D_{16}	29 mm
D_{50}	81 mm
D_{84}	209 mm
Shade	26%



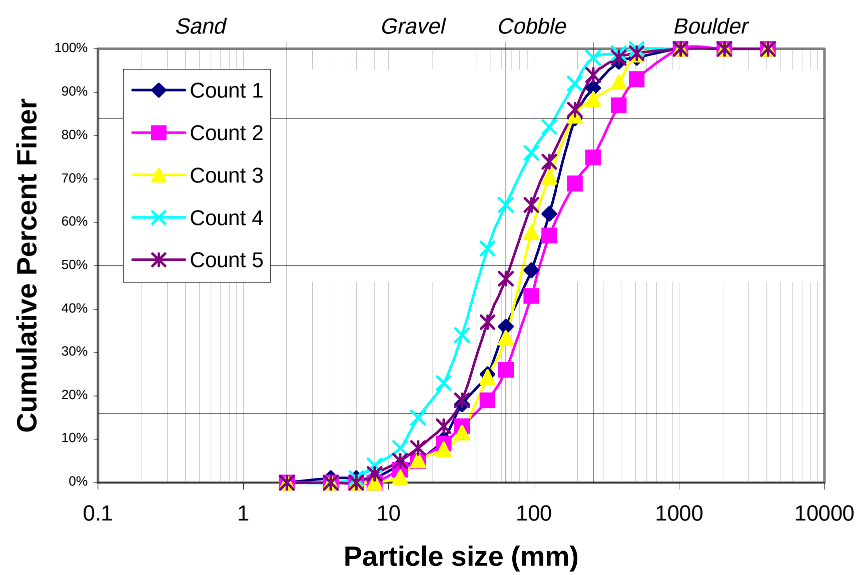


Figure 4-9. Summary data for 2001 Mainstem Green River Baseline Habitat Surveys, Reach 3.

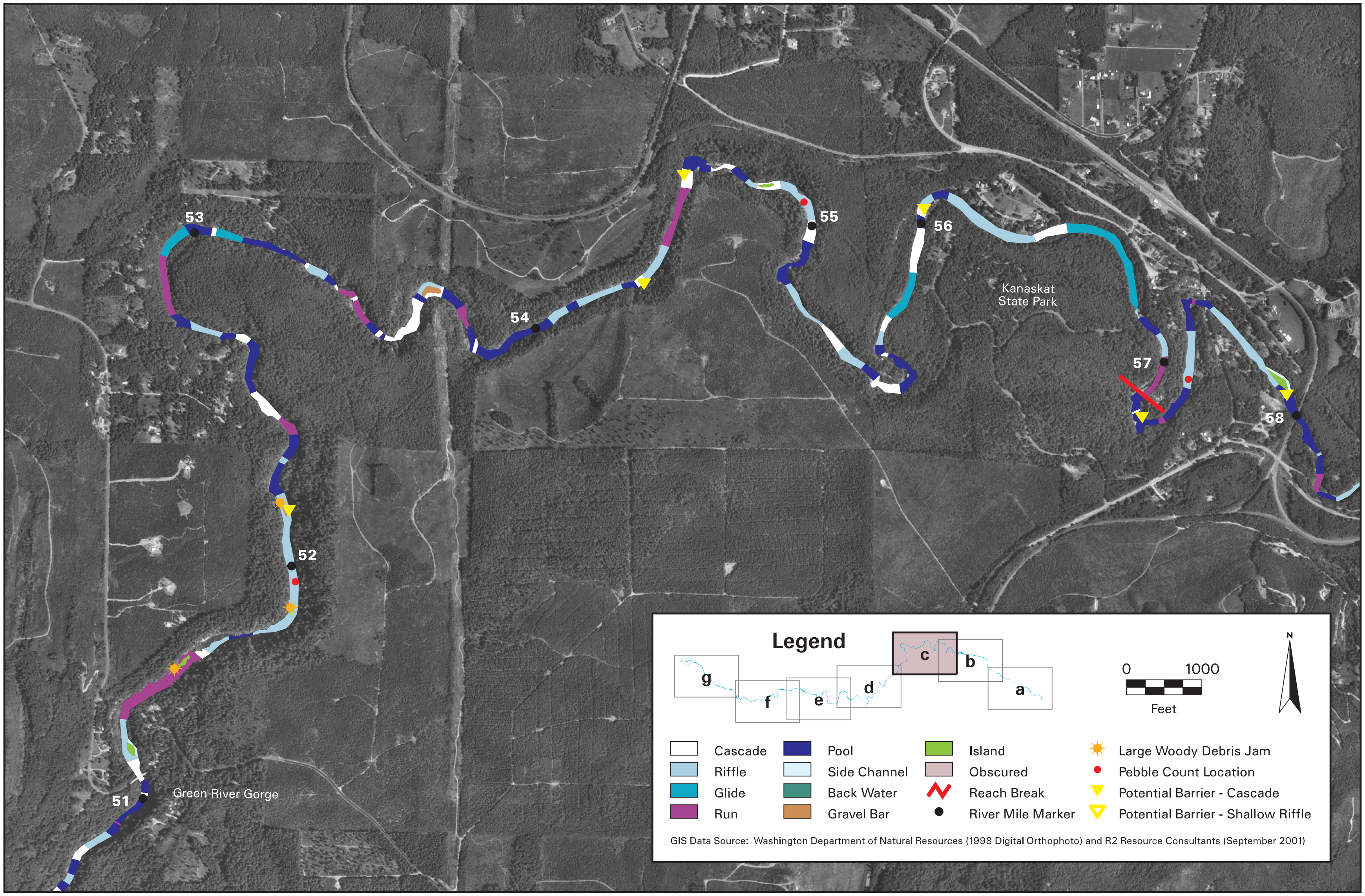


Figure 4–10a. Middle Green River physical habitat Reach 3 (Map c).

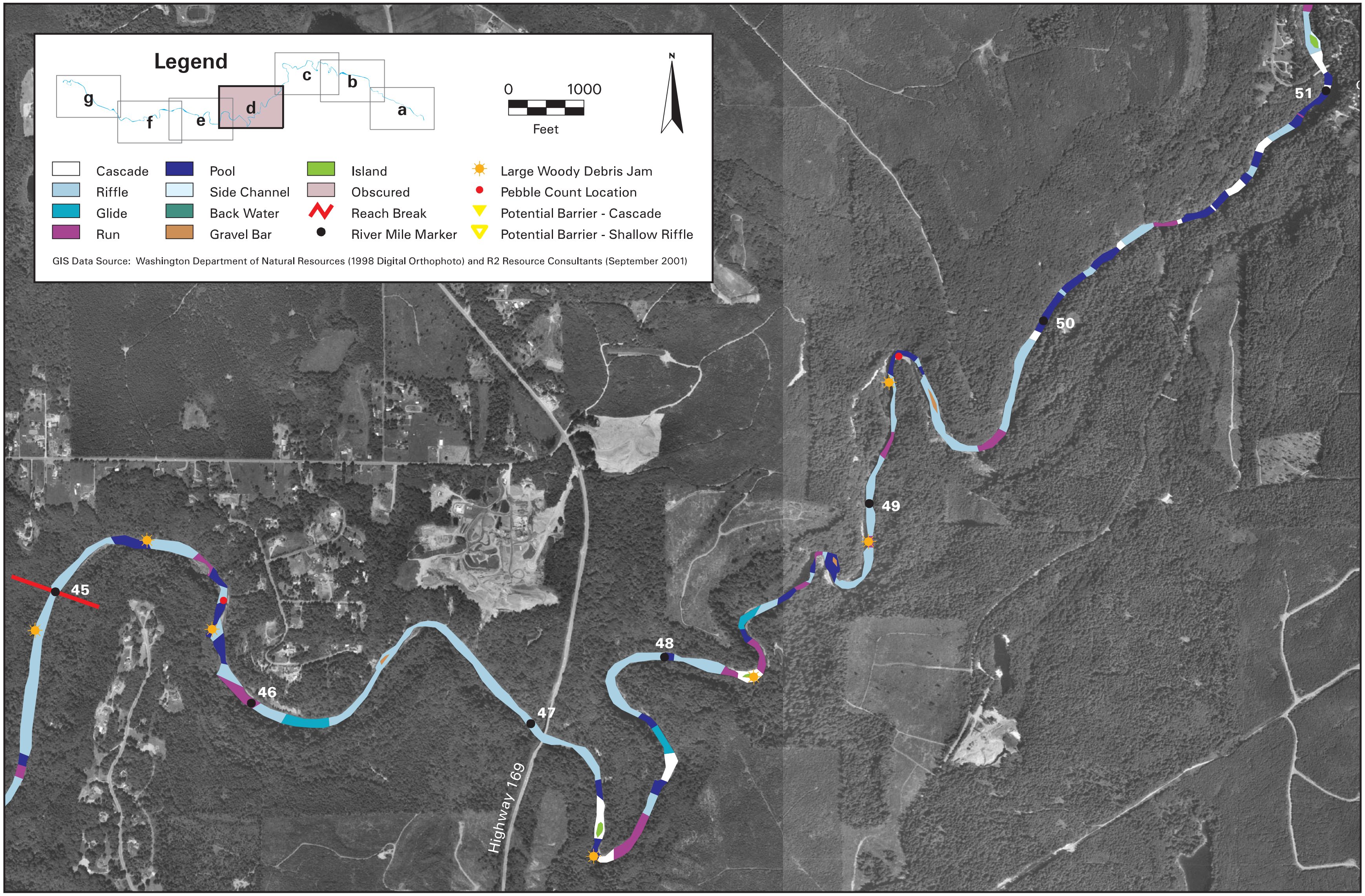


Figure 4–10b. Middle Green River physical habitat Reach 3 (Map d).

Figure 4-11. Bedrock shelf near RM 54, Reach 3, mainstem middle Green River, King County, Washington, August 14, 2001.

Fifty-four pools were identified in Reach 3, resulting in a pool spacing of 9 channel widths per pool (Figure 4-9). The majority of pools encountered in Reach 3 were formed by bedrock. Large woody debris was present in some pools, but in no case was it contributing to pool formation. Pools within Reach 3 were complex and deep, averaging 2.8 meters residual depth (Figure 4-9). Numerous pools deeper than 3 meters were encountered.

One hundred and sixty-four individual pieces of large woody debris and rootwads, including 11 key sized pieces, were identified in Reach 3 (Table 4-3). Of the individual pieces of LWD identified, 63 percent were located within Zone 1, interacting with the low flow channel. Eight small LWD jams were identified in Reach 3 (Figure 4-10a and b).

Reach 3 is a popular site for kayaking and rafting at high flows. Logs in the channel that pose a danger to boaters are routinely cut. Seven percent of the individual pieces of LWD in Reach 3 had cut ends. A number of newly recruited large trees that could pose a threat to boater safety were identified, photographed and mapped (Figure 4-12).

Substrate in Reach 3 is primarily boulder and bedrock. Pebble counts were conducted in riffle habitat types that tended to be composed of smaller material than was observed in steeper cascades and in pools. The mean D_{50} particle size of all five pebble counts was 81 mm, and the D_{50} ranged from 44 mm to 111 mm (Figure 4-9). Boulders larger than 256 mm comprised as much as 25 percent of individual counts.

Table 4-3. Zone and type of large woody debris in Reach 3, mainstem Green River habitat surveys, King County, Washington, 2001.

Zone	1	2	Total	Cut
Log-Medium	35	30	65	3
Log-Medium with Rootwad	20	11	31	2
Log-Large	13	15	28	0
Log-Large with Rootwad	18	6	24	1
Key Piece	6	5	11	3
Rootwad	2	3	5	0
Small Jam	7	1	8	1
Medium Jam	0	0	0	0
Large Jam	0	0	0	0

Figure 4-12. Newly recruited, channel-spanning large wood debris (LWD) near RM 52.4, Reach 3, mainstem middle Green River, King County, Washington August 15, 2001.

Gravel storage in Reach 3 was limited to pool tailouts and channel margin deposits. A large pool tailout deposit was noted in Pool 1, at the upstream end of the reach where the local gradient is somewhat lower than the reach average. Downstream of RM 56, gravel deposits were scarce until approximately RM 49. A large landslide at RM 49 has contributed a considerable amount of gravel to the river. The recent inputs of coarse sediment are apparent in the particle size distribution at pebble count site 4, which contains substantially more gravel and cobble size material than was encountered at other sites. The recent coarse sediment input has also resulted in the formation of small side and point bars that are not found elsewhere in the reach. Pool tailout deposits composed of gravel are also common downstream of the slide.

4.4 REACH 4

Reach 4 is a floodplain channel with predominantly pool-riffle bedforms and occasional transverse and point bars. Isolated levees or rip-rap constrain the bank protecting specific structures such as residences, bridges or county roads. The river flows through a mix of agricultural, rural residential and undeveloped park lands.

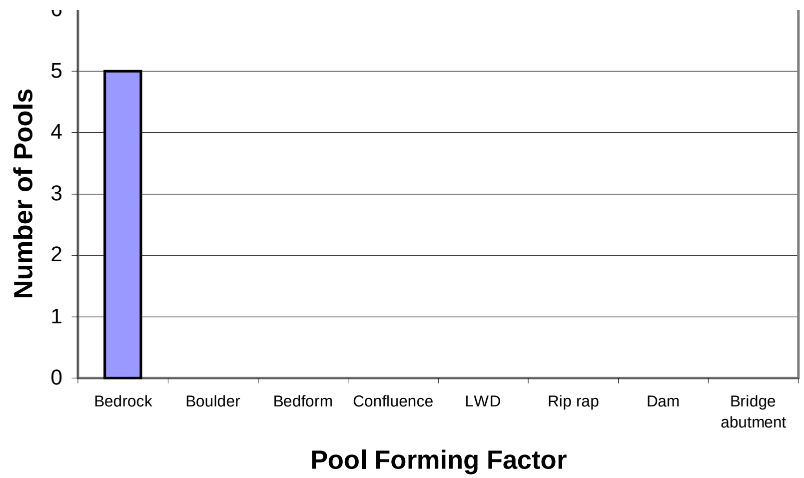
The mean bankfull channel width is 40 m, while mean wetted width is 31 m. Reach 4 has a gradient of 0.2 percent (Figure 4-1) and a sinuosity of 1.14. Flows at Auburn during the survey of Reach 4 ranged from 252 cfs on August 20 to 256 cfs on August 21. These flows represent typical summer low flow conditions.

Summary statistics for habitat data collected in Reach 4 are presented in Figure 4-13. The dominant habitat type is riffle, which comprises almost 50 percent of the habitat area (Figure 4-14). Glides are the next most common habitat type. Only 5 pools were identified in Reach 4, resulting in a pool spacing of 34 channel widths per pool (Figure 4-13). Pools comprised approximately 6 percent of the total habitat area. All pools encountered in Reach 4 were formed by bedrock, where the channel impinged directly on valley walls or encountered outcrops on the valley floor. None of the pools encountered were formed or influenced by LWD.

Thirty-three individual pieces of large woody debris and rootwads, including four key sized pieces, were identified in Reach 4 (Table 4-4). This included several rootwads that had been anchored in place beneath the bridge in Flaming Geyser Park. Of the individual pieces of LWD identified, over 80 percent were located within Zone 1, interacting with the low flow channel. Four small LWD jams were identified in Reach 4 (Figure 4-14).

Substrate in Reach 4 is primarily gravel and cobble. A large landslide at RM 42.5 affects downstream substrate size distributions. The average D_{50} particle size downstream of the landslide was 62 mm compared to 95 mm upstream of the slide. By RM 41, the D_{50} had increased back to 84 mm. In addition, pebble counts 5 and 6 downstream of the landslide contained more material smaller than 16 mm (Figure 4-13).

Summary Statistics	
Location	RM 40.8-RM 45
Channel Type	Pool Riffle
Confinement	Unconfined
Length	6,758 m
Gradient	0.20%
Flow at Auburn	252-256cfs
Flow at Palmer	112-114cfs
Average bankfull width	40 m
Average wetted width	31 m
Pool Frequency (CW/pool)	34
Percent pool by length	7%
Percent pool by area	4%
Average residual pool depth	2.5 m
Dominant pool forming factor	Bedrock
Pools formed by LWD	0%
Total LWD	33
LWD Frequency (Pieces/CW)	0.2
LWD/mile	7.9
Cut LWD	0%
Total # Key	4
Key Frequency	0.02
Total # Jams	5
% Small jams	100%
% Medium jams	0
% Large jams	0
D_{16}	36 mm
D_{50}	69 mm
D_{84}	138 mm
Shade	16%



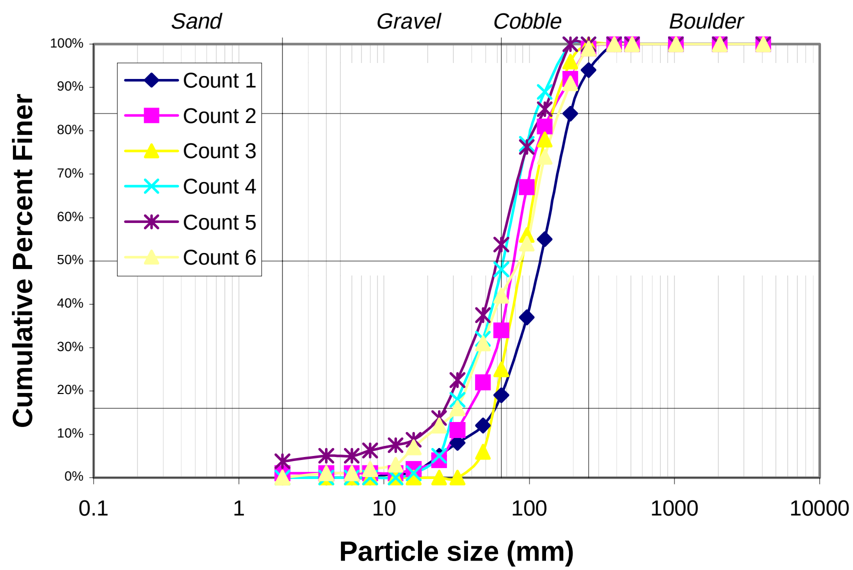


Figure 4-13. Summary data for 2001 Mainstem Green River Baseline Habitat Surveys, Reach 4.

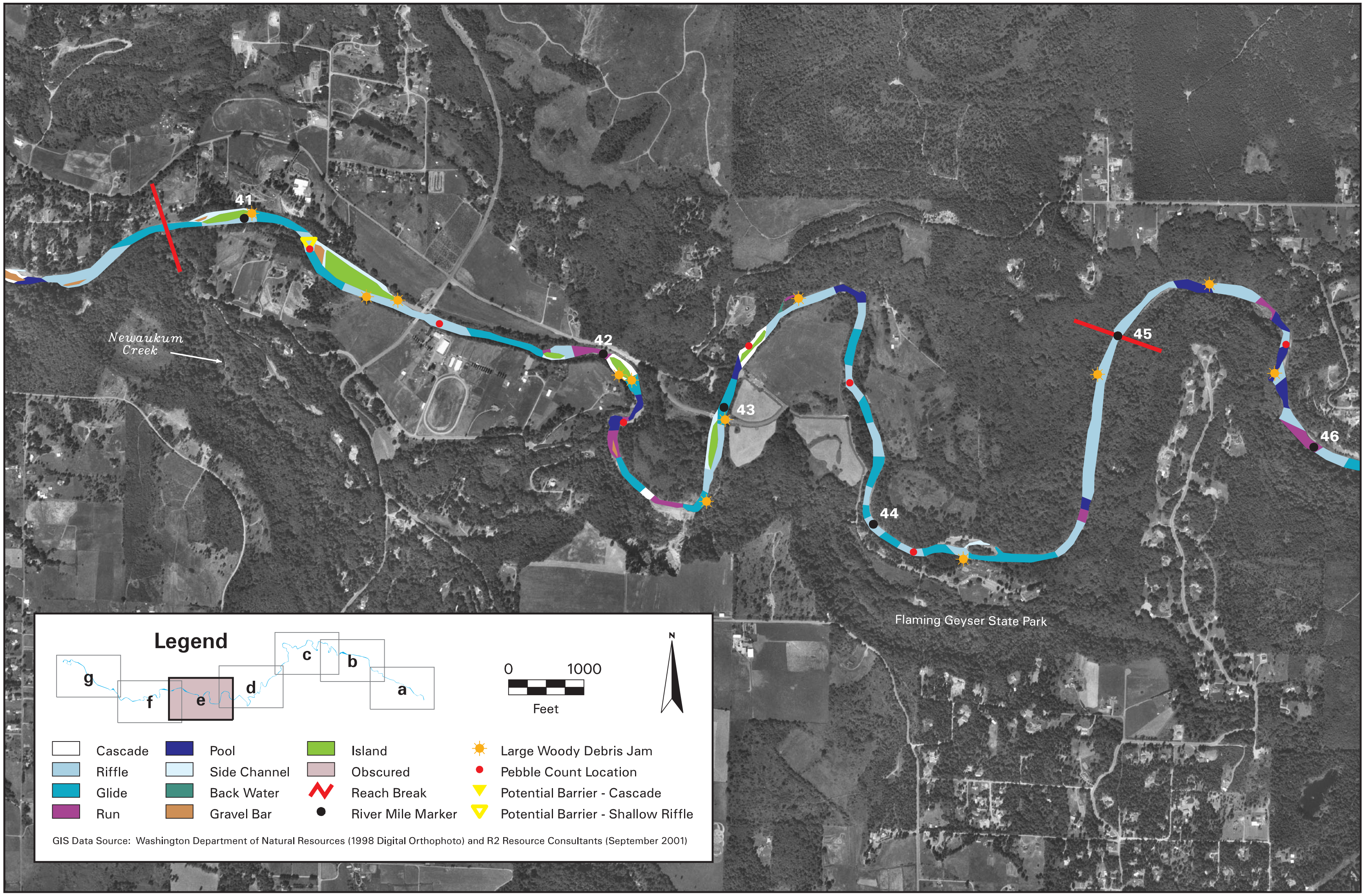


Figure 4-14. Middle Green River physical habitat Reach 4 (Map e).

Table 4-4. Zone and type of large woody debris in Reach 4, mainstem Green River habitat surveys, King County, Washington, 2001.

Zone	1	2	Total	Cut
Log-Medium	13	2	32	0
Log-Medium with Rootwad	7	2	21	0
Log-Large	0	1	2	0
Log-Large with Rootwad	2	1	5	0
Key Piece	4	0	3	0
Rootwad	1	0	8	0
Small Jam	5	0	4	0
Medium Jam	0	0	1	0
Large Jam	0	0	1	0

Although the dominant substrate is gravel and cobble, active bars are rare in Reach 4. Some gravel storage was noted in pool tailouts, but observers described the composition of these deposits as “mostly coarse” [cobbles]. Abundant surface fines were also noted in pool tailout deposits downstream of the landslide at RM 42.5.

One riffle with no flow paths greater than 1-foot deep was identified near RM 41 (Figure 4-14). However, it is unlikely that this site currently represents an impediment to the upstream migration of fish at typical low summer flow conditions.

4.5 REACH 5

Much of Reach 5 is a braided channel with multiple flow paths and large transverse and mid-channel bars. No levees or rip-rap constrain the bank, and the river flows through undeveloped park lands for much of its length. An exception occurs between RM 39 and 40 on the left bank, where agricultural development has resulted in clearing of the riparian zone up to the edge of the channel. This area is currently experiencing substantial bank erosion.

Reach 5 has experienced frequent channel shifts in the past 10 to 20 years and contains numerous side channels that were not surveyed as part of this mainstem habitat monitoring effort. Since the winter of 1996-1997, almost half of the mainstem flow has been flow redirected into a large side channel on the right bank near RM 41. This side channel was transmitting approximately 40-50 percent of the flow at the time of the 2001 surveys. This natural flow diversion has affected habitat within the mainstem survey reach. Substantial filling of pools and glides appears to have occurred since reconnaissance surveys of the same reach were conducted in August 1996. In addition, the wetted and bankfull channel widths were lower than would otherwise have been expected. The mean bankfull channel width is 40 m, while mean wetted width is 25 m. Reach 5 has a gradient of 0.3 percent (Figure 4-1) and a sinuosity of 1.12. Flows at Auburn during the survey of Reach 5 ranged from 256 cfs on August 21 to 356 cfs on August 22 when an unusually large August rainstorm rapidly increased inputs from tributaries in the middle Green River basin necessitating a delay in the field survey schedule.

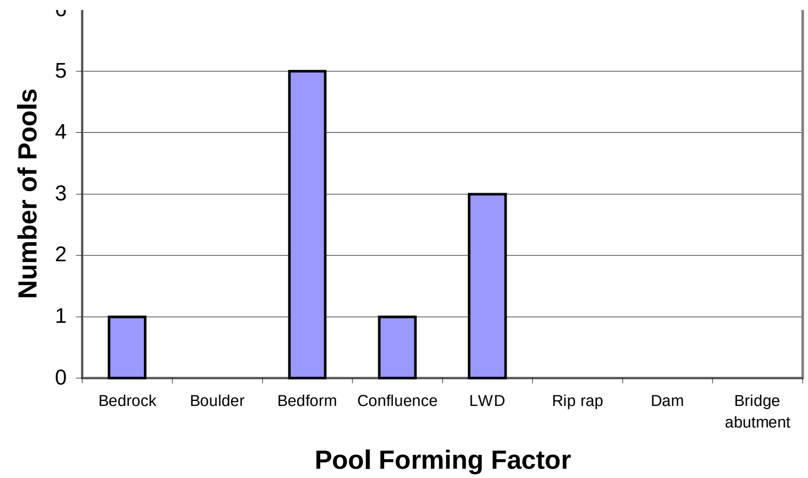
Summary statistics for habitat data collected in Reach 5 are presented in Figure 4-15. The dominant habitat types are riffle and glide, each of which comprised approximately 35 percent of the habitat by area (Figure 4-16). Pools and runs made up the remaining habitat area. A total of 10 pools were identified in Reach 5, resulting in a pool frequency of 11 channel widths per pool. Pools comprised approximately 18 percent of the total habitat by area. The dominant pool forming factor in Reach 5 is bedforms (Figure 4-15). Thirty percent of all pools identified were formed by wood.

Seventy individual pieces of pieces of large woody debris and rootwads, including 3 key sized pieces, were identified in Reach 5 (Table 4-5). Of the individual pieces of LWD identified, over 50 percent were located within Zone 1, interacting with the low flow channel. The majority of LWD currently present within Reach 5 was stored in log jams. Six LWD jams were identified in Reach 5, including one large meander jam containing over 100 individuals pieces of wood (Figure 4-17).

Substrate in Reach 5 is primarily gravel and cobble. The mean riffle D_{50} particle size over the five pebble counts conducted was 56 mm. The D_{50} ranged from 41 to 70 mm, and like Reach 6 no particles larger than cobbles encountered (Figure 4-15). The entire length of Reach 5 represents a depositional area where gravel is abundant. Transverse bars are common, and spawning gravel was present at all pool tailouts except where individual pools formed adjacent habitat units. Near RM 39.5 however, the channel has incised around a large point bar, and bar top gravels appear to be accessible only at flows greater than bankfull.

A number of riffles with no paths greater than 1-foot deep were identified in the segment affected by diversion of flow into the side channel (Figure 4-16). However, it is unlikely that any of these sites currently represents an impediment to the upstream migration of fish at typical low summer flow conditions. In addition, we assume that the narrower side channel is passable and would provide a means of avoiding shallow areas in the mainstem channel. No surveys of that side channel were conducted as part of the 2001 mainstem survey effort.

Summary Statistics	
Location	RM 38-RM 40.8
Channel Type	Braided
Confinement	Unconfined
Length	4,506 m
Gradient	0.30%
Flow at Auburn	256-356 cfs
Average bankfull width	40 m
Average wetted width	25 m
Pool Frequency (CW/pool)	11
Percent pool by length	24%
Percent pool by area	19%
Average residual pool depth	1.6 m
Dominant pool forming factor	Bedform
Pools formed by LWD	30%
Total LWD	70
LWD Frequency (Pieces/CW)	0.6
LWD/mile	25.0
Cut LWD	1%
Total # Key	3
Key Frequency	0.03
Total # Jams	6
% Small jams	67%
% Medium jams	17%
% Large jams	16%
D_{16}	25 mm
D_{50}	56 mm
D_{84}	99 mm
Shade	14%



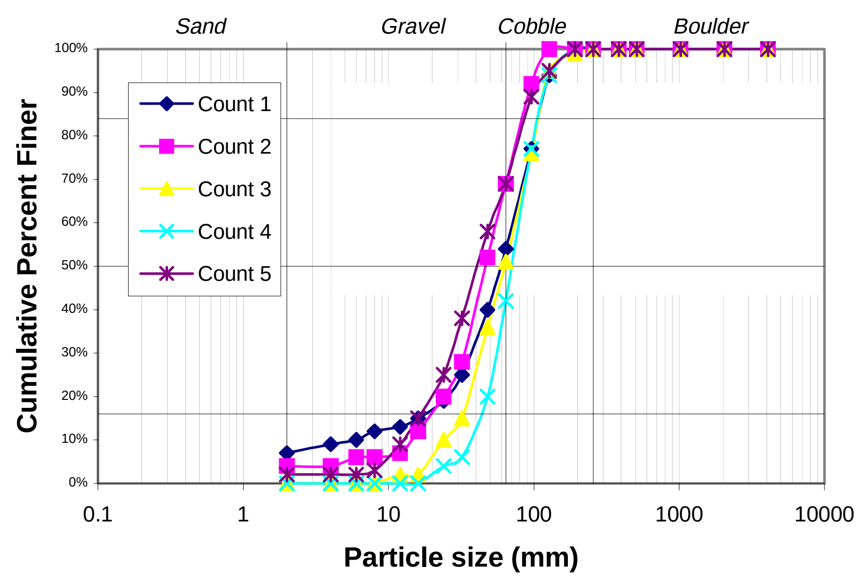


Figure 4-15. Summary data for 2001 Mainstem Green River Baseline Habitat Surveys, Reach 5.

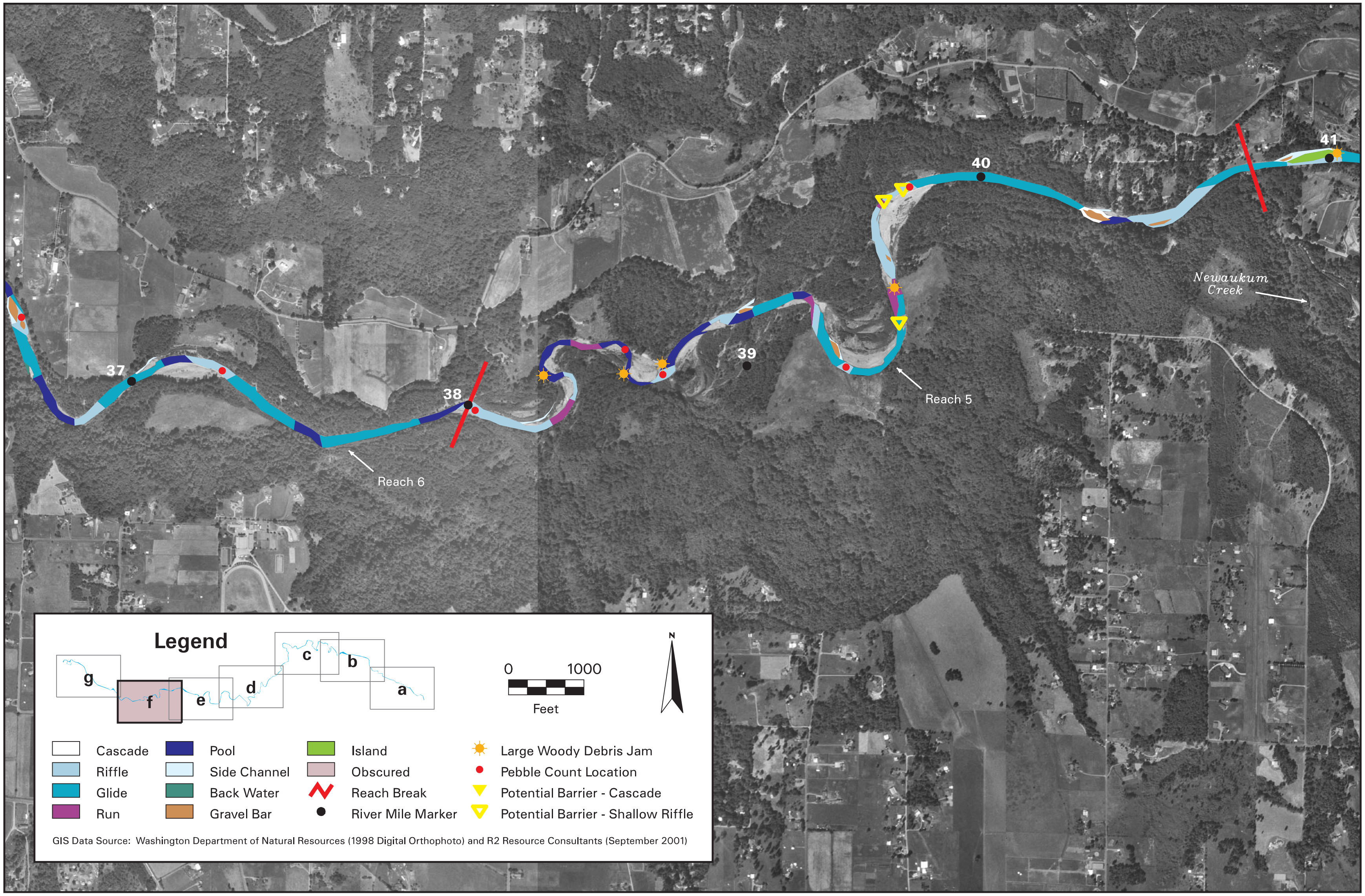


Figure 4-16. Middle Green River physical habitat Reaches 5 and 6 (Map f).

Table 4-5. Zone and type of large woody debris in Reach 5, mainstem Green River habitat surveys, King County, Washington, 2001.

Zone	1	2	Total	Cut
Log-Medium	18	13	32	0
Log-Medium with Rootwad	12	9	21	0
Log-Large	0	2	2	0
Log-Large with Rootwad	4	1	5	1
Key Piece	2	1	3	0
Rootwad	5	3	8	0
Small Jam	4	0	4	0
Medium Jam	1	0	1	0
Large Jam	1	0	1	0

Figure 4-17. Large LWD jam near RM 38.4, Reach 5, mainstem middle Green River, King County Washington, August 21 2001.

4.6 REACH 6

Reach 6, historically an unconfined alluvial floodplain channel, is currently constrained between levees for most of its length. Agricultural and rural residential development extends to the channel margins in many areas and riparian vegetation is limited. Reach 6 has a gradient of 0.2 percent (Figure 4-1) and an average bankfull width of 45 meters. Sinuosity is 1.25. Flows at

Auburn during the survey of Reach 6 ranged from 326 cfs on August 22 when surveys were discontinued due to heavy rain and high flow, to 266 cfs when surveys were completed on August 29. The mean bankfull channel width is 45 m, while mean wetted width is 30 m.

Summary statistics for habitat data collected in Reach 6 are presented in Figure 4-18. The dominant habitat type is glide, which comprised more than 40 percent of the habitat by area (Figures 4-16 and 4-19). The next most common habitat is riffle, which accounted for about 31 percent of the habitat area.

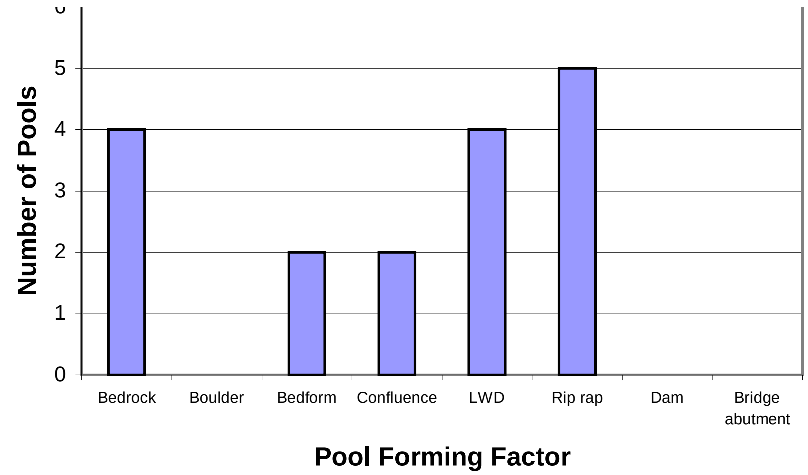
A total of 17 pools were identified in Reach 6, resulting in a pool frequency of 12 channel widths per pool. Pools comprised 21 percent of the total habitat by area. The dominant pool-forming factor in Reach 6 was rip-rap (Figure 4-18). Twenty-four percent of all pools identified were formed by wood.

One hundred and thirty one individual pieces of pieces of large woody debris and rootwads were identified in Reach 6 (Table 4-6). Of the individual pieces of LWD identified, over 70 percent were located within Zone 1, interacting with the low flow channel. Of all individual pieces of LWD identified, only three were sufficiently large to be classified as key pieces. A total of four LWD jams were identified in Reach 6, including one very large jam located at Auburn Narrows near RM 31 (Figure 4-19). This LWD jam was composed of hundreds of pieces of LWD (Figure 4-20).

Substrate in Reach 6 is primarily gravel and cobble. The mean riffle D_{50} particle size over the five pebble counts conducted was 42 mm. The D_{50} ranged from 36 to 47 mm, and in no case were particles larger than cobbles encountered (Figure 4-18). Gravel is plentiful, stored in point bars and occasional transverse bars as well as along channel margins. Gravel storage was also documented in almost every pool tailout except where pools transitioned into deep run or glide habitat units. Surveyors occasionally noted the presence of abundant surface fines in pool tailout deposits.

No potential physical barriers or impediments to upstream migration were identified in Reach 6; however, due to recent rain events flows during the surveys were higher than would be expected during extreme drought years under the AWSP.

Summary Statistics	
Location	RM 32-RM 38
Channel Type	Channelized
Confinement	Unconfined
Length	9,656 m
Gradient	0.20%
Flow at Auburn	266-300 cfs
Average bankfull width	45 m
Average wetted width	30 m
Pool Frequency (CW/pool)	12
Percent pool by length	23%
Percent pool by area	14%
Average residual pool depth	2.0 m
Dominant pool forming factor	Rip-rap
Pools formed by LWD	24%
Total LWD	45
LWD Frequency (Pieces/CW)	0.6
LWD/mile	22.0
% Cut LWD	0%
Total # Key	13
Key Frequency	0.01
Total # Jams	13
% Small jams	80%
% Medium jams	6000%
% Large jams	20%
D_{16}	22 mm
D_{50}	42 mm
D_{84}	80 mm
Shade	13%



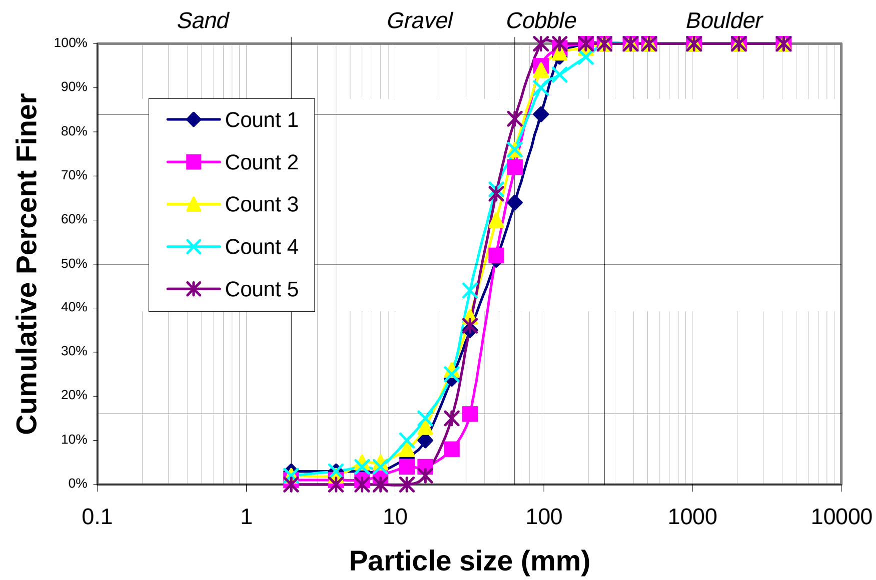


Figure 4-18. Summary data for 2001 Mainstem Green River Baseline Habitat Surveys, Reach 6.

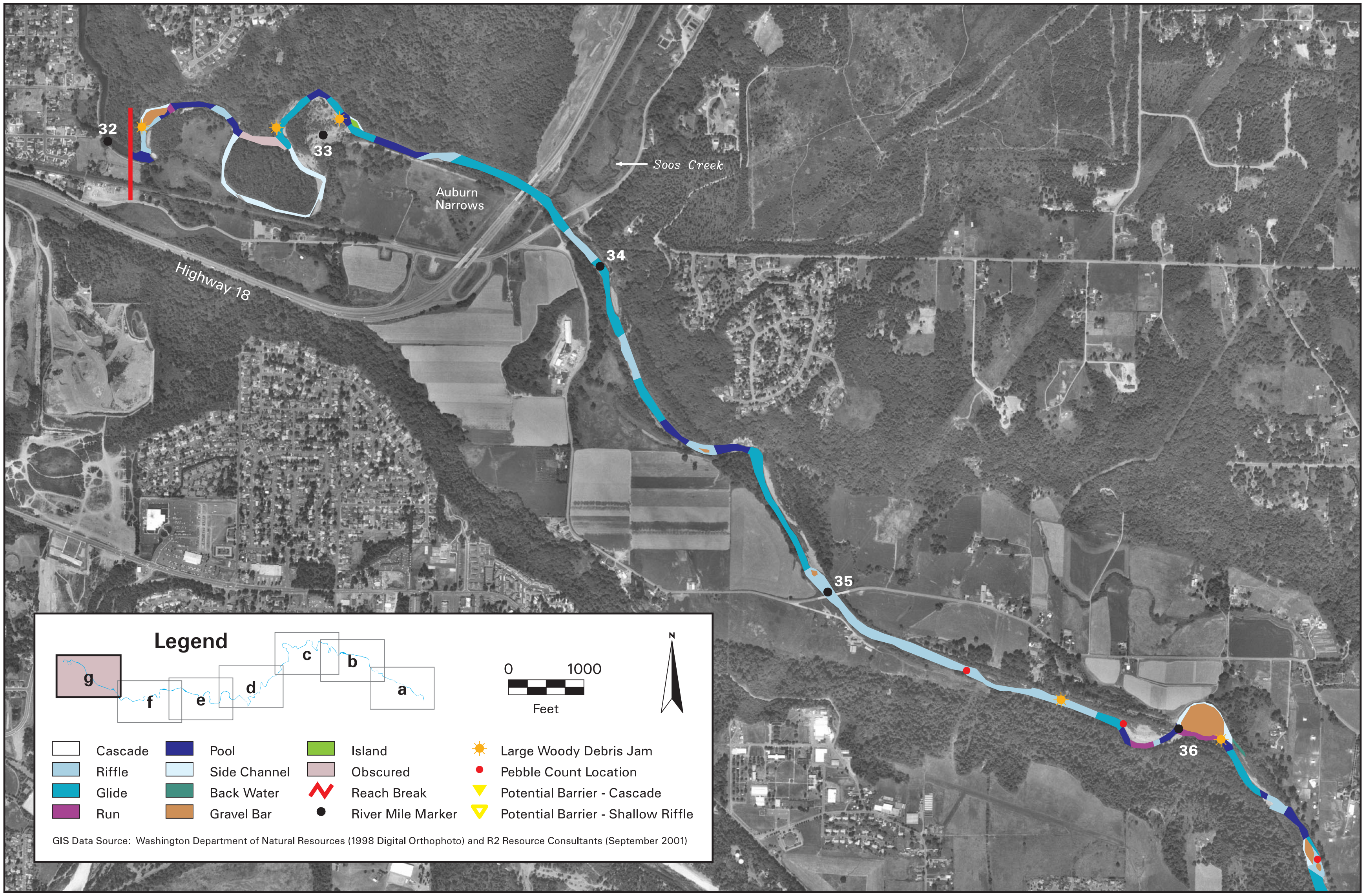


Figure 4-19. Middle Green River physical habitat Reach 6 (Map g).

Table 4-6. Zone and type of large woody debris in Reach 6, mainstem Green River habitat surveys, King County, Washington, 2001.

Zone	1	2	Total	Cut
Log-Medium	23	9	32	0
Log-Medium with Rootwad	29	10	39	0
Log-Large	2	5	7	0
Log-Large with Rootwad	17	7	24	0
Key Piece	1	2	3	0
Rootwad	21	5	26	0
Small Jam	4	0	4	0
Medium Jam	0	0	0	0
Large Jam	1	0	1	0

Figure 4-20. Large LWD jam located near RM 32.8, Reach 6, mainstem middle Green River, King County, Washington, August 29 2001.

4.7 QUALITY ASSURANCE/QUALITY CONTROL

4.7.1 Equipment Calibration and Gear

Field equipment used to measure habitat attributes was checked for damage and calibrated at the beginning and end of field work. Table 4-7 lists equipment used to conduct habitat monitoring surveys for baseline monitoring of the mainstem middle Green River in 2001.

Table 4-7. Equipment used to conduct habitat surveys for baseline monitoring of the mainstem middle Green River in 2001.

Item	Size	Accuracy	Condition
Magellan GPS 310 Satellite Navigator	NA	± 15 m[1]	Good
Bushnell Yardage Pro 800 Laser Rangefinder	NA	±2m	Good
Wading Rod	1.8 m	±0.05m	Good
Depth Sounder	10 m	±0.05m	Good
Convex Spherical Densiometer	Handheld	NA	Good
LWD Calipers	24 inches	1/8 inch	Good
Retractable tape	3.0	±1mm	Good
Laminated 1: 8400 aerial photographs	Enlarge 2x	NA	Fair to good
Disposable Waterproof 35 mm Camera	Handheld	NA	Fair

[1]Non-differentially corrected data

Laser Rangefinders were checked by sighting to a clear, stationary target then measuring the distance to that target. The rangefinders digital readout displays distances to within ± 2 meters. Calibration indicated that distances were generally accurate to within 2 meters over a distance of 50 meters under clear weather conditions.

Wading rods and depth sounders were checked by comparing them to metric surveyors tapes. Rods and depth sounders were graduated in units of 0.10 meters, with 0.05 m intervals marked. Wading rods were replaced or remarked several times during the surveys to maintain readability. Reaches 4, 5, and 6 were surveyed by two crews of two in 15-foot canoes. Weather conditions were generally warm and dry and crew members dressed in wading shoes and shorts or chest waders. One crew collected data on bankfull widths, canopy cover, LWD and conducted pebble counts, while the second crew mapped habitat units and measured pools.

Reaches 1, 2, and 3 were surveyed by a single two person crew in float tubes. Crew members dressed in wading shoes and shorts or drysuits, depending on weather conditions.

4.7.2 Categorical Data Collection

Two approximately 1-mile long channel segments were resurveyed on September 13 2001 for QA/QC purposes. These reaches were located between RM 55.5 and 56.2 (QA/QC Segment 1) and between RM 45 and RM 46.1 (QA/QC Segment 2). These channel segments were selected because:

- each contained at least three pool habitat types;
- each contained at least one pebble count site; and
- each was readily accessible to the QA/QC field team.

Each QA/QC Reach was designated prior to initiating repeat surveys. Field photos marked with target bankfull width and pebble count data collection sites were carried by the QA/QC team. Target sites marked on the photos were re-located based on landmarks that could be clearly identified in the field.

The QA/QC team mapped habitat units on each field photo using the same procedures as the original surveys. All habitat units originally identified by the field survey crew were confirmed by the QA/QC crew.

4.7.3 Repeat Surveys

Channel Geometry and Shade

Data were collected at five transects within each QA/QC Segment. These data were compared to original field survey data to assess the precision of channel geometry measurements (Table 4-8). Most individual wetted and bankfull width measurements were within ±10 percent of the original value, but there were larger excursions at some sites. The differences could result from either measurer bias or variability in the specific locations where data was collected. Channel geometry data collection sites were not monumented, but simply approximately reoccupied according to the original field notes.

Overall, the average bankfull width and wetted width of the entire QA/QC segment was within ±2-4 meters of the original survey, which suggests that differences can be attributed primarily to variability in the data collection sites and equipment accuracy rather than measurement error. The objective of this aspect of the long term monitoring program is to track reach scale changes in habitat, thus comparisons with future data should focus on changes in reach averages rather than at individual sites. The precision of individual site measurements could be improved by monumenting each channel geometry measurement site; however, that would substantially increase the level of effort associated with this monitoring program. We anticipate that more precise data on shorter control and treatment sub-segments will be collected as part of the associated site-specific monitoring program.

Table 4-8. Results of quality assurance/quality control (QA/QC) surveys for width and shade, mainstem Green River Washington, 2001.

Reading	**Bankfull Width (m)**	**QA/QC (m)**	**Diff.**	**%**	**Wet width (m)**	**QA/QC (m)**	**Diff.**	**%**	**Shade**	**QA/QC (m)**	**Diff.**
QA/QC Segment 1 RM 55.5 to RM 56.2											
1	54	54	0	0	52	50	+2	4	7	10	**+3**
2	42	36	-6	14	22	26	+4	18	8	18	**+10**
3	28	40	+12	43	24	34	+10	42	23	13	**-10**
4	38	40	+2	5	34	28	-6	18	11	13	**+2**
5	37	40	+3	8	34	36	+2	6	35	26	**-9**
Average	**40**	42	+2	8	33	35	+2	10	17	16	**-0.5**
QA/QC Segment 2 RM 45 to RM 46.1											
1	60	64	+4	7	56	56	0	0	14	9	**-5**
2	56	45	-11	20	30	32	+2	7	11	10	**-1**
3	56	66	+10	18	46	60	+14	30	15	21	**+6**
4	38	38	0	0	28	30	+2	7	30	22	**-8**
5	38	40	+2	5	30	32	-2	7	24	23	**-1**
Average	**50**	**51**	**+1**	**2**	**38**	**42**	**+4**	**10**	**19**	**17**	**-2**

Pool Habitat Units

Each habitat unit originally identified as a pool during habitat surveys was also identified as a pool in QA/QC surveys. No pools not originally identified were detected. Furthermore, in each case the factor identified as responsible for forming the pool was consistent between surveys.

Data for QA/QC purposes was collected for three pools in Segment 1 and four pools in Segment 2. These data were compared to original field survey data to assess the precision of pool habitat unit measurements (Table 4-9). Individual measurements of pool length varied by as much as 20 meters. Average pool width, based on a series of 3 to 6 measurements perpendicular to the pool centerline, was generally within about 5 meters of the original, although in one case (Pool 1 QA/QA Segment 1) it varied by more than 22 meters. As a result of these variations, pool area (pool length x average pool width) was also highly variable. In the case of variations in channel width, the magnitude of error was similar to differences recorded as a result of instrument limitations during calibration surveys (±2-3) meters. In the case of Pool 1 in QA/QC Segment 1, the large error was confirmed to be result of measurer bias resulting from the difficulty in accurately identifying pool boundaries in complex bedrock and boulder controlled pools. The complexity of large, deep pools also affected our ability to accurately and repeatably measure residual pool depths and widths.

The magnitude of variation observed between repeat measurements of the same pools by different pools for this study is consistent with the results of other studies completed on the repeatability of habitat surveys elsewhere in the Pacific Northwest (Ralph et al. 1994; Pleus 1994). The high degree of variability typical of reach scale habitat surveys is a major limitation to the use of habitat mapping data for long-term monitoring of individual pools. Thus, for the purposes of long term monitoring, attention should focus on changes in the number, distribution and formative factor of pools at the reach scale rather than on attempting to discern differences in individual pool characteristics. The results of these initial surveys further support the need for supplementing the monitoring program with intensive surveys of control and treatment reaches as a part of site-specific monitoring.

Table 4-9. Results of quality assurance/quality control (QA/QC) surveys for pool habitat units, mainstem Green River Washington, 2001.

Pool #	Original Length (m)	QA/QC Length (m)	Diff.	%	Original Average Width (m)	QA/QC Average Width (m)	Diff.	%	Original Residual Depth (m)	QA/QC Residual Depth (m)	Diff.
QA/QC Reach 1 RM 55.5 to RM 56.2											
1	54	74	+21	+37%	23	33.2	+10.2	+44%	2	1.4	+0.6
2	56	58	+16	+4%	21.5	25.6	+4.0	+19%	2.5	2.4	-0.1
3	36	44	+8	+22%	22	27.6	+5.0	+23%	2	1.8	-0.2
4	214	210	+4	+2%	25.3	26.4	+1.1	+4%	5.0	5.4	+0.4
QA/QC Reach 2 RM 45 to RM 46.1											
1	146	154	+8	+5%	19	22	+3	+16%	3.1	3.6	+0.5
2	116	112	-3	-3%	21	26	+5	+24%	3.0	3.1	+0.1
3	124	144	+20	+16	22	21	-1	-5%	2.2	2.5	+0.4

Pebble Counts

A total of three pebble counts were repeated for QA/QC purposes. One of the QA/QC pebble counts was conducted in each of the QA/QC segments. Both of these sites were characterized by mixed particle sizes ranging from gravel to boulders. To test for differences in repeatability between channel types, a third pebble count was repeated in a more homogenous alluvial floodplain channel type at the upstream end of Reach 4.

Original and repeat pebble counts conducted in each of the QA/QC segments exhibited statistically significant differences ($\alpha = 0.05$) in the mean particle size (Table 4-10). Studies suggest that measurer bias and measurement error using the pebble count technique are generally minimal (Wohl et al. 1996). However, large variations in particle size distributions are typical of poorly-sorted bedrock and boulder controlled channels (Church et al. 1987) and suggests that substantially larger samples sizes will be required to accurately identify changes in the substrate size distribution in Reaches 1, 2 and 3. Additional sampling should be conducted during the proposed HEMP study and monitoring to identify appropriate sample sizes.

Table 4-10. Results of ANOVA testing for pebble count data collected during baseline habitat monitoring of the mainstem middle Green River, King County Washington, 2001.

Group	Count	Mean (mm)	Variance	P-Value[1]	D_{16} (mm)	D_{50} (mm)	D_{84} (mm)
Reach 3 Count 1	100	125	12,190	0.005	28	98	192
Repeat	100	180	25,390		66	126	287
Reach 3 Count 5	100	98	8,029	0.00006	26	68	180
Repeat	100	162	15,681		52	121	289
Reach 4 Count 1	100	127	5,523	0.25	54	118	192
Repeat	100	139	6,460		66	121	208

The repeat pebble count conducted in the well-sorted riffle at the upstream end of Reach 4 was not significantly different ($\alpha = 0.05$) from the original survey. This indicates that counts of 100 pebbles should be adequate to monitor changes in substrate size distributions at selected locations in Reaches 4, 5, and 6.

LWD Calibration

Team leaders jointly estimated then measured the length and width of the first 46 pieces of LWD encountered. The individual with the lower error rate continued to be responsible for LWD measurement and estimation when the crews split into two teams, measuring then estimating an additional 19 pieces of LWD until a consistent 10 percent error rate was achieved. Overall, the average error rate ranged from 8 to 16 percent for piece width and was 14 percent for piece width. An error rate of less than 10 percent for piece width, the variable used to classify individual pieces, was achieved after measuring a total of 65 pieces. The primary LWD observer misclassified only 7 of the 65 measured pieces, and 6 of the 7 were among the first 38 pieces measured. In only one case would the estimated count have included a piece of LWD that otherwise did not meet the criteria for an individual piece.

4.8 CONCLUSION

Habitat maps and data resulting from this study provide a useful means of tracking reach scale changes in habitat condition. Reach scale descriptors of habitat conditions that may be used for monitoring future changes in habitat include:

- pool frequency;
- the number of pools greater than one meter deep in each reach;
- the number of pools formed by LWD in each reach;
- average bankfull and wetted width;
- average canopy cover;
- LWD frequency;
- key piece frequency; and
- number of LWD jams.

The average riffle D_{50} is also a useful indicator of habitat condition in low gradient reaches (Reaches 4 and 5). However, accurate enumeration of the riffle D_{50} in higher gradient reaches will require repeated counts of more than 100 pebbles per site. Table 4.11 provides summary statistics for each reach.

4.9 RECOMMENDATIONS

Reach scale habitat surveys should be repeated at 5-year intervals during and immediately after implementation of the AWSP and GD ERP. Changes in habitat conditions are expected to occur rapidly as construction commences. Following completion of construction, habitat surveys should be repeated at 10 year intervals to track the effectiveness of the integrated restoration programs over the long-term.

Reach scale habitat data should not be used to track changes in the characteristics of individual habitat units that result from construction of individual restoration projects. An overall site-specific monitoring program should be developed to standardize survey and data collection techniques and ensure that data are comparable and repeatable. Individual restoration and mitigation projects should develop monitoring plans that provide for collection of baseline data

Table 4-11. Reach scale summary statistics from baseline physical habitat monitoring conducted in the mainstem middle Green River in 2001.

	Summary Statistics					
Reach	**1**	**2**	**3**	**4**	**5**	**6**
Location	RM 61-RM 64.5	RM 57-RM 61	RM 45-57	RM 40.8-RM 45	RM 38-RM 40.8	RM 32-RM 38
Channel Type	Large Contained	Pool-Riffle	Large Contained	Pool Riffle	Braided	Channelized
Confinement	Confined	Unconfined	Confined	Unconfined	Unconfined	Unconfined
Length	5,632	6,437 m	19,311 m	6,758 m	4,506 m	9,656 m
Gradient	0.90%	0.80%	0.80%	0.20%	0.30%	0.20%
Average bankfull width	33 m	41 m	39 m	40 m	40 m	45 m
Average wetted width	27 m	32 m	28 m	31 m	25 m	30 m
Pool Frequency (CW/pool)	13	11	9	34	11	12
Percent pool by length	20%	26%	25%	7%	24%	23%
Average residual pool depth	2.7 m	3.0 m	2.8 m	2.5 m	1.6 m	2.0 m
Dominant pool forming factor	Bedrock	Bedrock	Bedrock	Bedrock	Bedform	Rip-rap
Pools formed by LWD	0%	0%	0%	0%	30%	24%
Total LWD	18	36	164	33	70	45
LWD Frequency (Pieces/CW)	0.1	0.2	0.3	0.2	0.6	0.6
LWD/mile	5.1	9.0	13.7	7.9	25.0	22.0
% Cut LWD	6%	0%	7%	0%	1%	0%
Total # Key	1	2	11	4	3	13
Key Frequency	0.01	0.01	0.02	0.02	0.03	0.01
Total # Jams	0	0	8	5	6	13
D_{50} [1]	158 mm	137 mm	81 mm	69 mm	56 mm	42 mm
Shade	15%	17%	26%	16%	14%	13%

[1]D50 based on count of 100 pebbles. QA/QC data suggest accurate quantification of reach scale average D_{50} requires count of more than 100 pebbles

and specify the nature and timing of post-construction surveys prior to construction of the projects.

Implementation of the gravel nourishment program is expected to result in pronounced changes in substrate conditions, particularly in reaches where gravel is placed. Changes in gravel storage are best documented by intensive surveys of areas where gravel is likely to accumulate. Detailed maps of existing spawning gravel patches and areas of potential gravel storage should be developed prior to gravel placement. Monitoring of spawning gravels should focus on areas of existing or potential storage in Reaches 2 and 3, and in Reach 1 if gravel is placed there. The maps contained in Appendix 4 identify such sites and may be used to guide future intensive monitoring efforts.

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APPENDIX A

Summary of Green River Habitat Monitoring Workshop

INTRODUCTION

As part of the Additional Water Storage Project, the U.S. Army Corps of Engineers and Tacoma Public Utilities are funding long-term monitoring of habitat conditions within the 12,000 cfs floodplain of the middle Green River, Washington. The purpose of long-term monitoring in the middle Green River is to demonstrate the effects of proposed conservation measures at reducing or reversing the decline of natural processes and conditions in the middle Green River.

In 2001 baseline habitat monitoring will be initiated. The intent of baseline monitoring is to document current habitat conditions using a standardized methodology that will provide a reference point from which changes or trends in aquatic habitat conditions can be demonstrated. Data gathered during baseline habitat monitoring will be made available for use by all entities undertaking habitat restoration activities in the Green River watershed.

In support of these monitoring efforts, on May 4 2001 the U.S. Army Corps of Engineers and Tacoma convened a monitoring workshop to solicit input from regulatory agencies, tribes and other entities currently involved in the planning or implementation of habitat restoration programs in the Middle Green River. The goal of this workshop was to catalog restoration projects or programs that will be implemented in the middle Green River in the near future, compile a list of contacts for each of these projects or programs, and to develop a standardized approach for reach scale monitoring. A proposed approach, including suggested key monitoring parameters and data measurement standards was presented to workshop participants to solicit feedback and suggestions for modifications and improvement. The intent is to facilitate efficient data collection, prevent duplication of efforts and promote coordination and cooperation among those involved in restoration of the Green River Watershed.

SUMMARY

The workshop was facilitated by Sue Madsen and Phil Hilgert of R2 Resource Consultants**.** Participants were asked to introduce themselves and give a brief synopsis of management, restoration or monitoring projects they are currently involved with in the middle Green River. A list of meeting participants and other entities currently known to be working in the middle Green River was compiled, including their affiliations, a brief project description and contact information (See Attachment 2).

Next, Phil Hilgert presented a general overview of monitoring and led a discussion of the scope of this workshop. In order to accomplish stated workshop goals, discussions were limited to 1) monitoring of physical habitat characteristics, 2) at a reach scale, 3) in the middle Green River. The need for monitoring of biological variables and site-specific restoration projects was identified, but were not discussed at this monitoring workshop in order to maintain focus and complete stated workshop goals.

Workshop Outline and Handouts

May 4, 2001
09:00-15:30
Tacoma Public Utilities Auditorium
Conference Room
3628 South 35th Street
Tacoma, Washington

MEETING AGENDA

Goal: Cooperatively identify key monitoring parameters, definitions and data management standards for use in long-term monitoring programs in the Middle Green River to facilitate data sharing and consistency between user groups.

1. Introduction

2. Scope of Workshop 9:15-9:30
   - Physical Habitat
   - Reach scale vs site specific
   - Middle Green River RM 33.8-64.5

3. Reach Scale Aquatic Habitat Monitoring
   - A. Approach
   - B. Key Monitoring Parameters
     - Parameter Definitions
     - Data/measurement standards

4. Lunch

5. Site-Specific Monitoring
   - A. Approach
   - B. Key Monitoring Parameters
     - Parameter Definitions
     - Data/measurement standards
   - C. Examples
     - i. Engineered Log Jams (Phil Roni - NMFS - invited)
     - ii. Levee Improvements (John Koon - King County - invited)

WORKSHOP PARTICIPANTS

Name	Representing	Current Projects in Green River Basin	Phone/E-mail address
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Detailed Workshop Outline

As part of the Additional Water Storage Project, the U.S. Army Corps of Engineers and Tacoma Public Utilities will fund long-term monitoring of habitat conditions within the 12,000 cfs floodplain of the Middle Green River from Howard Hanson Dam (RM 64.5) downstream to the Soos Creek confluence (RM 33.8). The purpose of long-term monitoring in the middle Green River is to: 1) demonstrate the effects of proposed conservation measures at re-establishing natural processes and conditions, and 2) to facilitate estimation of potential changes in salmon and steelhead production as a result of changes in habitat quality and quantity.

In 2001, the U.S. Army Corps of Engineers will initiate baseline habitat monitoring. Baseline monitoring will document the current habitat conditions using a standardized methodology and will provide a reference point from which changes or trends in aquatic habitat conditions can be demonstrated.

In support of these monitoring efforts, the U.S. Army Corps of Engineers and Tacoma are convening a monitoring workshop to solicit input from regulatory agencies, tribes and other entities currently involved in the planning or implementation of habitat restoration programs in the Middle Green River. The goal of this workshop is to identify a common basemap, standardized approach, key monitoring parameters and data standards that will facilitate efficient data collection, prevent duplication of efforts and promote coordination and cooperation among those involved in restoration of the Green River Watershed.

Reach Scale Habitat Monitoring

A. Monitoring Approach

Monitoring plan developed by:

1) Identifying key parameters that should be included in all reach scale monitoring surveys
2) Identifying additional parameters required to address specific AWSP concerns

Survey Reach extends from RM 64.5 (HHD) to RM 33.8 (Soos Creek

Survey Reach will be stratified based on channel type/landuse factors as follows:

Reach 1: RM 64.5 (HHD) to RM 61 (Tacoma Headworks)
Reach 2: RM 61 (Tacoma Headworks) to RM 57 (Kanasket Park)
Reach 3: RM 57 (Kanasket Park) to RM 45 (Flaming Geyser Park)
Reach 4: RM 45 (Flaming Geyser Park) to RM 40.0 (Newaukum Creek)
Reach 5: RM 37 (Metzler-O'Grady Park) to RM 40 (Newuakum Creek)
Reach 6: RM 33.8 (Soos Creek) to RM 37 (Metzler-O'Grady Park)

Survey Designs Considered:

1. Ground mapping of entire study reach: quantitative surveys of key parameters
2. Sub-sampling: quantitative surveys of key parameters in randomly selected reaches
3. Sub-sampling: quantitative sampling of key parameters in randomly selected habitat units; estimation of all units.

Recommendation: Ground mapping of entire study reach

B. Key Monitoring Parameters – See Attachments 1 -3

Recommendation:

Key Reach Scale Monitoring parameters (quantitative measurement)	Additional AWSP Parameters
Bankfull Width	Level II Habitat unit type
Location and Type of hydromodified bank	Pool formative factor
Basic habitat unit type	Rootwad on key LWD
Pool length	Debris jam type
Pool width	Spawning gravel availability
Maximum pool depth	% Surface fines
Residual pool depth	Low flow barriers
# Qualifying LWD	
# Key LWD	
# jams	
Riffle particle size distribution	
Shade	

C. Parameter Definitions - See Attachment 4

Bankfull width

Bankfull width is distance between the bankfull channel edges, which are defined by the floodplain elevation, bank morphology and composition and vegetation. All methodologies reviewed utilized similar narrative definitions based on general geomorphic principals.

Hydromodified Banks

Hydromodified banks are defined as riverbanks that have anthropogenically altered. Classify as levee, rip rap, bulhead or other. If other, describe narratively.

Basic Habitat Unit Types:

Alternatives:
1) Simple - Assume unit is riffle (fastwater) unless it meets definition of pool
2) Complex system based on Bisson 1982/Hawkins et al. 1993

Recommendation: Primary habitat type of interest is pools. Recommend using the simple system described by the TFW Ambient Monitoring as this allows for quantitative definition of habitat unit types based on depth and surface gradient and has proven to be repeatable over time with variable surveyors. Encourage further qualitative stratification of habitat units as supplementary data on project specific basis (e.g., mainstem surveys conducted for AWSP will go to Hawkins et al. Level II).

Habitat Unit Size

Alternatives:
1) > 50 percent wetted width
2) Minimum size = $5m^2$ (Existing TFW criteria for channels with a BFW>20m)
3) Minimum size =$10m^2$ (Extrapolated from existing TFW criteria based on BFW)

Recommendation: Minimum size =$10m^2$

Pool

Alternatives:
1) Define qualitatively based on water surface gradient and relative depth and velocity
2) Minimum residual depth = 0.4 m (Existing TFW criteria for channels with a BFW>20m)
3) Minimum residual depth = 2.1 m (Extrapolated from existing TFW criteria based on BFW)

Recommendation: Minimum size =0.4m

LWD

Alternatives:
1) Minimum diameter = 10 cm (4 in); Minimum length=2m (6.5 ft)
2) Minimum diameter = 15 cm (6 in); Minimum length=3m (10 ft)
3) Minimum diameter = 30 cm (12 in); Minimum length=3m (10 ft)

Recommendations: Minimum diameter = 30 cm (12 inches)
Minimum length=3m (10 feet)

Key Piece

Alternatives:
1) Minimum diameter = 60 cm (24 in); Minimum length=15 m (49 ft)
2) Minimum diameter = 70 cm (28 in); Minimum length=24m (74 ft)
3) Minimum diameter= 85 cm (34 in); Minimum length= 10 m (35 ft)

Recommendation: Minimum diameter = 85 cm (34 inches)
Minimum length=10m (35 feet)

Jam
Alternatives:
1) More than 2 qualifying pieces that touch
2) More than 4 qualifying pieces that touch
3) More than 10 qualifying pieces that touch

Recommendation: More than 10 qualifying pieces that touch

Substrate size classes for riffle particle size distribution

Alternatives:
1) Wentworth Scale (see Attachment 3)
2) Modified Wentworth scale (see Attachment 3)
3) Commonly used fisheries scale (see Attachment 3)

Recommendation: Wentworth Scale

Shade

Blockage of view to sky caused by vegetative canopy or topographic relief

D. Suggested Minimum Data Standards

Reach Scale Mapping
- Locate reach end points using GPS
- Record or measure flow weekly or at survey start and end (whichever is more frequent)
- Photograph looking upstream each 1000 m
- Record equipment used to conduct survey
- Record parameters measured, definitions and data standards
- Record measurement units
- Record calibration information

Bankfull Width

- Measure to nearest meter using surveyors tape or rangefinder
- Evaluate every 1000m
- Use default method described by TFW Ambient Monitoring protocol to designate bankfull edge on both banks: work from known to unknown; when no longer certain, identify edge as point in elevation midway between two last known points.

Habitat unit dimensions (non-pool)

- Estimate maximum length of non-pool units to the nearest meter using hip chain or calibrated laser rangefinder

Pool Area

- Measure maximum length to the nearest meter using surveyors tape or calibrated laser rangefinder
- Measure width to nearest foot at ¼, ½ and ¾ length using surveyors tape or calibrated laser rangefinder
- Record pool location on map using GPS or by marking the location on copies of low-level aerial photographs based on landmarks that are recognizable from both field and photo

Pool Depth

- Measure maximum depth to nearest 0.1 m using survey rod or graduated measuring rod with at least 0.1 m increments.
- Measure pool outlet depth to nearest 0.1 m

Large Woody Debris

- Tally individual pieces by size class as follows:

  30-50 cm
  50-85 cm
  >85 cm, length 3-10m
  >85 cm, length >10m (key)
  Rootwad (bole diameter> 30 cm; length<3m)

- Record debris jam locations using GPS or by marking the location on copies of low-level aerial photographs based on landmarks that are recognizable from both field and photo
- Tally each jam and estimate the number of qualifying pieces of large woody debris (10-50 pieces; 50 to 100 pieces; >100 pieces)
- Classify jam as meander, bar apex, side channel inlet or other (Abbe and Montgomery 1996)

Riffle Particle Size Distribution

- Occularly estimate the dominant and subdominant particle size of each habitat unit using the Wentworth scale

- Conduct Wolman pebble count in at least 5 randomly selected riffles per channel segment. Measure at least 100 particles

Shade
- Estimate overhead canopy cover every 1000 m using densiometer
- Collect measurement in center of wetted channel

Site Specific Habitat Monitoring

A. Approach

Alternatives:
1) Pre and post-project
2) Control/Treatment

Recommendation: At a minimum pre-project and post project surveys of habitat and channel morphology in the vicinity of the project site should be conducted. Surveys should be conducted immediately before and after construction (same season), once the year following construction and once thereafter six to ten years after construction.

B. Key Monitoring Parameters

In general, key monitoring parameters for site-specific projects are similar to those for reach scale monitoring. Additional parameters that should be assessed appear in bold:

Bankfull Width
Longitudinal (thalweg) profile
Non-pool habitat unit types
Non-pool habitat unit length
Non-pool habitat unit width
Pool length
Pool width
Maximum pool depth
Residual pool depth
Pool formative factor
Qualifying LWD
Key LWD
jams
Spawning gravel availability
Substrate particle size distribution
Bank Composition

Riparian community type

Additional parameters specific to each site will be identified based on project specific goals and objectives.

D. Parameter Definitions (additional)

Longitudinal profile
Topographic survey of bed elevation in the channel thalweg throughout the project site

Non-pool habitat types
The level of detail required for non-pool habitat types will vary depending on project specific goals and objectives. No specific non-pool habitat definitions are mandated, but we recommend that cooperating entities utilize the hierarchical system developed by Hawkins et al. 1993 (See USFS R1/R4 list on Attachment 3)

Spawning gravel
The TFW Ambient Monitoring program has identified two classes of spawning gravel:

8-64mm	Used by small-bodied salmonids
64-128 mm	Used by large-bodied salmonids

Stream bank

Bank = area between the top of regularly wetted channel substrate and the bankfull channel margin

Bank Material classes:

- Soil (few visible roots)
- Root mat (More visible roots than soil)
- Sand (<2mm)
- Gravel (2-64mm)
- Cobble (64-256mm)
- Boulder (>256mm)
- Bedrock
- Artificial (provide description)

Riparian Community Type
Classify as follows:

- Bare
- Developed
- grass/forbs
- shrubs

small hardwood trees (<30 feet tall)
hardwood trees (>30 feet tall)
small conifer trees (<30 ft tall)
conifer trees (>30 feet tall)
large conifer trees (>24” diameter)

E. Suggested Minimum Data standards

Because of the more focused nature of site-specific monitoring projects, quantitative data collection and measurement standards for key parameters are more precise. In general, we recommend that data collection and measurement standards follow protocols outlined in the TFW Ambient Monitoring Manuals, except as modified below.

<u>Site Mapping</u>
- At a minimum, site-specific surveys should extend 50 meters upstream and 7 bankfull widths downstream of the project area
- Locate monitoring reach end points using GPS
- Mark monitoring reach end points with permanent reference points
- Estimate bankfull width to nearest 1 m every 100 m
- Record bank composition and riparian composition on the basemap
- Photograph looking upstream each 100 m
- Record equipment used to conduct survey
- Record parameters measured, definitions and data standards
- Record measurement units

<u>Longitudinal profile</u>
- Survey in a longitudinal profile of the entire monitoring reach using an autolevel or total station
- Establish a permanent benchmark to ensure comparability of post-project re-surveys

<u>Habitat unit dimensions (all units)</u>
- Measure the maximum length of each habitat units to the nearest 1/10 meter using tape measure
- Measure maximum length to the nearest 1/10 meter using tape measure
- Measure width to nearest ½ meter at ¼, ½ and ¾ distance using tape measure

<u>Pool Depth</u>
- Measure maximum depth to nearest 0.1 meter using survey rod or graduated measuring rod with at least 0.1 meter increments.
- Measure pool outlet depth to nearest 0.1 meter

<u>Pool formative factor</u>
- Record the formative factor of each qualifying pool

Large Woody Debris

- Follow TFW Level 2 survey protocols
- Measure individual piece diameter and length to the nearest 0.1 meter
- Classify as Zone 1 (wetted) or Zone 2 (w/in bankfull channel)
- Record debris jam locations using GPS or by marking the location on copies of low-level aerial photographs based on landmarks that are recognizable from both field and photo
- Tally each jam and estimate the number of qualifying pieces of large woody debris (10-50 pieces; 50 to 100 pieces; >100 pieces)

Substrate Particle Size Distribution

- Occularly estimate the dominant and subdominant particle size of each habitat unit using the Wentworth scale
- Conduct one Wolman pebble count per 100 meters, measuring at least 100 particles
- Map spawning gravel availability using the transect method over the entire project site (if less than 200 meters long) or in at least 10 percent of the monitoring reach for project sites longer than 200 metes. Segments of long project reaches selected for subsampling will be selected randomly

Shade

- Estimate overhead canopy cover every 100 m using densiometer
- Collect measurement in center of wetted channel

Attachment 1. Summary of habitat assessment and monitoring methods reviewed for applicability to the proposed Howard Hanson Dam Additional Water Storage Project Baseline Habitat Monitoring Program

				Parameters Measured			
Habitat Assessment Method	**Author(s), Date**	**Primary Objectives**	**Approach**	**Physical**	*Chemical*	**Biological**	**Strengths and Weaknesses of Approach**
TFW Ambient Monitoring Program Manual	Schuett-Hames, D., A. Pleus, L. Bullchild, and S. Hall 1994 (note: modules updated as stand alone in 1999)	Repeatable survey methodology for detecting and documenting changes in habitat conditions over time.	Subsample randomly selected reaches	• Reference points • Photographs • Discharge • Bankfull width • Bankfull depth • Canopy cover • Habitat unit type • Habitat unit dimensions • Pool formative factor • LWD count • Key piece count • LWD jams • % fines • Location and area of suitable spawning gravel • Dominant substrate size • Spawning gravel scour • Riparian stand conditions • LWD recruitment	• Temperature (continuous recorder or max-min)	None	*Strengths:* • Set of linked or stand alone modules providing detailed survey methodology, equipment needs, field forms and data analysis information • Inventory data is stratified by channel type • Hierarchical survey design to support more or less detailed data collection as needed • Quantifiable and repeatable measurement standards • Provides information on developing statistically sound project approach • Support system including data management, training and QA/QC • Measurement parameters clearly specified to minimize sampler bias • Identification of habitat units, spawning gravel availability independent of discharge • Stream size considered when defining parameter criteria • Provides framework for interpreting data (WFPB 1997) *Weaknesses:* • Designed for small streams (<20 m BFW); some measurements difficult to apply in larger rivers • Time, labor and data intensive if applied as presented • No biological component

				Parameters Measured			
Habitat Assessment Method	**Author(s), Date**	**Primary Objectives**	**Approach**	**Physical**	*Chemical*	**Biological**	**Strengths and Weaknesses of Approach**
King County Stream Inventory Level 1, 2 and 3	King County Building and Land Development 1991 see also O'Rollins, W. L. 1997 and Scholz, J. G. and D. B. Booth 1999	To collect data that may be used to evaluate instream habitat, riparian condition, and fish use prior to permitting activities which could alter fish habitat.	Sample entire length of non-randomly selected reach (project specific)	• Habitat unit type • Habitat unit dimensions • Average channel width (wetted and OHWM) • Average channel depth (wetted and OHWM) • Riparian community type • Riparian community age • Riparian buffer width • Dominant and subdominant substrate • Pool quality • LWD (length, diameter, stability, type and condition) • Cross-sections • Pebble Count • Species, size and position of riparian trees		• Fish presence (2-pass electrofishing) • Documentation of habitat requirements and use • Spawning surveys • Macroinvertebrates (Level 3)	*Strengths:* • Standardized reporting form and data collection methods for measuring common attributes. • Hierarchical survey design to support more or less detailed data collection as needed • Includes biological component *Weaknesses:* • Designed for project level assessments, not long-term monitoring • Designed for small streams (<20 m BFW); some methods difficult to apply in larger rivers • Parameter definitions, measurement standards not clearly specified • Identification of habitat units, spawning areas dependent on discharge • Does not provide a methodological framework for integrating and interpreting data. • No discussion of statistical validity of sampling design • No existing centralized database • No recommendations for training, QA/QC

				Parameters Measured			
Habitat Assessment Method	**Author(s), Date**	**Primary Objectives**	**Approach**	**Physical**	*Chemical*	**Biological**	**Strengths and Weaknesses of Approach**
ODFW Stream Habitat Methods	Moore, K. K. Jones. and J. Dambacher 1995	To provide quantitative information on habitat condition for streams throughout Oregon.	Sub-sample every 10th habitat units	• Channel type • Gradient • Photographs • Discharge • Riparian community type • Habitat unit type • Habitat unit dimensions • Canopy cover • Shade • Bankfull width • Bankfull depth • Inter-terrace width • Terrace height • Substrate • Boulder count • Bank condition • LWD count • LWD complexity rating • LWD type and volume	• Temperature	• none	*Strengths:* • Inventory data is stratified by channel type • Provides semi-quantitative definitions of measured parameters • Data compiled in centralized database • Provides framework for interpreting data *Weaknesses:* • Designed for small streams (<20 m BFW); some methods difficult to apply in larger rivers • Does not provide a methodological framework for integrating and interpreting data • Identification of habitat units, spawning gravel availability independent of discharge • Stream size considered when defining parameter criteria • Measurement standards not clearly specified • No discussion of statistical validity of sampling design • Data intensive • No recommendations for training, QA/QC

				Parameters Measured			
Habitat Assessment Method	**Author(s), Date**	**Primary Objectives**	**Approach**	**Physical**	*Chemical*	**Biological**	**Strengths and Weaknesses of Approach**
BC Fish and Fish Habitat Inventory	BC Ministry of Fisheries 1998	To provide information about fish distribution, population status, and the condition and capability of supporting habitats.	Subsample randomly selected habitat units	• Discharge • Channel Type • Evidence of recent disturbance • Location of physical barriers • Bankfull channel width and depth • Wetted width and depth • Maximum pool depth, riffle crest depth, residual depth • Pool type • Spawning gravel amount and type • LWD-total • LWD-functional • Cover • Riparian vegetation type • Riparian structural stage • Overhead Canopy closure • Photographs	• Temperature (spot check during survey) • Inorganic nutrients • pH • Turbidity	• Fish distribution and relative abundance	*Strengths:* • Inventory data is stratified by channel type • Stream size considered when defining parameter criteria • Standardized reporting form and data collection methods for measuring common attributes. • Includes biological component and relevant WQ data • Provides quantitative definition of parameters • Provides framework for interpreting data *Weaknesses:* • Method intended for assessment and restoration prescription development, not monitoring • Focuses on degraded habitats rather than representative sample • No recommendations for training, QA/QC • Biologic sampling not systematic • Measurement standards not clearly specified • Designed for small streams (<20 m BFW); some methods difficult to apply in larger rivers • Data intensive • No centralized database

Attachment 2. Parameters assessed by various habitat inventory and monitoring programs (TFW 2000; USFS R6 1998; USFS R1/R4 1997; ODFW 1995; WRP 1996)

Channel	**Banks**	**Habitat**	**LWD**	**Substrate**	**Riparian**
Inter-terrace width	% eroding	Habitat unit type	# of qualifying pieces	Dominant substrate size by unit	Vegetation type
Terrace height	Composition	Habitat unit length	# of functional pieces	Subdominant substrate size by unit	Age
Gradient	Length/location of hydromodified banks	Habitat unit area	# of key pieces	Particle size distribution	Riparian buffer width
Discharge	Undercut length	Pool formative factor	# of LWD jams	Embeddedness	Canopy cover/ shade
Bankfull width	Undercut depth	Pool quality	LWD length	Percent surface fines	LWD recruitment
Bankfull depth	Slope	Maximum pool depth	LWD diameter	Percent fines-volumetric/wgt	Species, size and position of riparian trees
Floodprone width		Riffle crest depth	LWD stability	Location and area of suitable spawning gravel patches	# of conifers
Floodprone depth		Residual depth	LWD species	Gravel - % area	
Wetted width		Pocket pool frequency	LWD condition	Silt/Sand/ Organics - % area	
Wetted depth		# pools > 1m deep	LWD volume	Spawning gravel scour	
Cross-section		Cover	LWD complexity rating	Boulder count	
Disturbances		Step-pool total		Q*	
Photographs		Qualitative Habitat Index (QHI)			
Location of physical barriers		V*			
Height of physical barriers					
# Road crossings					
# of Stormwater outfalls					

Attachment 3. Habitat evaluation procedures that recommend quantitative criteria to assess channel condition.

Metric	NMFS 1999	WFPB 1997	ODFW 1997	May 1996	B.C. WRP 1985
Pools					
Length		x		x	x
Area			x	x	
Frequency	x	x	x	x	x
Depth			x		
Wood cover		x	x		x
Cover				x	
LWD					
Frequency (total)	x	x	x	x	x
Volume			x		
# key pieces		x	x	x	x
Channel					
W/D ratio	x		x		
Bank stability (% eroding)	x				
Substrate					
Embeddedness	x				
% fines		x		x	
Gravel (% area)			x		
Silt sand (%area)			x		
D_{10}				x	
Boulder cover					x
Riparian					
Shade (% cover)			x		
Frequency of large conifers in RMZ			x		

Attachment 4. Definitions of key parameters specified in five commonly used habitat assessment methodologies.

Minimum Habitat unit size

TFW 2000	USFS R10	USFS R1/R4	WRP 1996	ODFW 1995
$5m^2$	entire wetted width	>50% wetted width	none	length>wetted channel width

Recommendation: Quantitative numeric standard preferred to minimize surveyor bias. TFW standard is specific to channels < 20m wide. Scaling TFW minimum unit area requirements up to a channel width representative of the Middle Green (approximately 50m) gives minimum unit area of 10 m^2

Habitat Unit Types

TFW 2000	USFS R10	USFS R1/R4	WRP 1996	ODFW 1995
Pool	Pool	Fast	Pool	Pool
Riffle	Backwater	Turbulent	Riffle	Plunge
Subsurface	Scour	Cascade	Glide	Straight scour
Obscured	Slough	Step-run	Side channel	Lateral scour
Wetland	Fastwater	High-gradient riffle		Trench
	Glide	Low-gradient riffle		Dammed
	Riffle	Non-turbulent		Beaver dam
	Cascade	Glide		Glide
		Run		Riffles
		Slow		Riffle
		Dammed		Riffle w/pockets
		Main channel		Rapids
		Backwater		Rapid w/boulders
		Scour		Rapid over bedrock
		Lateral		Cascades
		Mid-channel		Boulder cascade
		Plunge		Bedrock cascade
		Underscour		Steps
				Boulder step
				Cobble step
				Bedrock step
				Log step
				Structure step
				Dry unit
				Puddled unit

Attachment 5. Suggested minimum data measurement standards for Reach Scale habitat monitoring

Reach Scale Mapping
- Locate reach end points using GPS
- Record or measure flow weekly or at survey start and end (whichever is more frequent)
- Photograph looking upstream each 1000 m
- Record equipment used to conduct survey
- Record parameters measured, definitions and data standards
- Record measurement units
- Record calibration information

Bankfull Width
- Measure to nearest meter using surveyors tape or calibrated laser rangefinder
- Evaluate every 1000 m
- Use default method described by TFW Ambient Monitoring protocol to designate bankfull edge on both banks: work from known to unknown; when no longer certain, identify edge as point in elevation midway between two last known points.

Habitat unit dimensions (non-pool)

- Estimate maximum length of non-pool units to the nearest meter using hip chain or calibrated laser rangefinder
- Estimate average wetted width using surveyors tape or calibrated laser rangefinder

Pool Area
- Measure maximum length to the nearest meter using surveyors tape or calibrated laser rangefinder
- Measure width to nearest 1 m at ¼, ½ and ¾ length using surveyors tape or calibrated laser rangefinder
- Record pool location on map using GPS or by marking the location on copies of low-level aerial photographs based on landmarks that are recognizable from both field and photo

Pool Depth
- Measure maximum depth to nearest 0.1 m using survey rod or graduated measuring rod with at least 0.1 m increments.
- Measure pool outlet depth to nearest 0.1 m

Large Woody Debris

- Tally individual pieces by size class as follows:
  30-50 cm
  50-85 cm
  >85 cm, length 3-10m
  >85 cm, length >10m (key)
  Rootwad (bole diameter> 30 cm; length<3m)

- Record debris jam locations using GPS or by marking the location on copies of low-level aerial photographs based on landmarks that are recognizable from both field and photo
- Tally each jam and estimate the number of qualifying pieces of large woody debris (10-50 pieces; 50 to 100 pieces; >100 pieces)
- Classify jam as meander, bar apex, side channel inlet or other (Abbe and Montgomery 1996)

Riffle Particle Size Distribution

- Occularly estimate the dominant and subdominant particle size of each habitat unit using the Wentworth scale

- Conduct Wolman pebble count in at least 5 randomly selected riffles per channel segment. Measure at least 100 particles

Shade

- Estimate overhead canopy cover every 1000 m using densiometer
- Collect measurement in center of wetted channel

Green River Mainstem Habitat Monitoring Workshop

Sponsored by:

USACE, Seattle District and

Tacoma Water

Workshop Goals

- Achieve a better understanding of other players and restoration activities
- Develop a list of reach scale monitoring parameters that will be measured in the mainstem middle Green River on a repeated basis
- Develop a list of site-specific monitoring parameters for consideration when planning restoration projects
- Receive a meeting summary and attendee list that will help you coordinate your middle Green River activities with other parties working in the basin

Agenda

1. Introduction
2. Scope of Green River Monitoring Workshop
    - Physical Habitat
    - Reach Scale and Site-Specific
    - Middle Green River
3. Reach Scale Aquatic Habitat Monitoring
    - A. Approach
    - B. Key Monitoring Parameters
        - Definitions
        - Data/Measurement Standards
4. Lunch
5. Site Specific Monitoring
    - A. Approach
    - B. Key Monitoring Parameters
        - Definitions
        - Data Measurement Standards
    - C. Examples

Overview

- Assessment=evaluation of conditions at a single point in time
- Monitoring=a series of measurements repeated over time

"*Habitat assessment procedures generally lack the sensitivity necessary to detect environmentally significant change. To be useful… habitat variables need to be measured with a known degree of precision and accuracy"*

Bauer, S.B. and S.C. Ralph 1999. Aquatic habitat indicators and their application to water quality objectives within the Clean Water Act. U.S. EPA, Region 10, Publication EPA 910-R-99-014. 99 p.)

Scope of Green River Monitoring Workshop

- Physical Habitat
- Reach Scale and Site Specific Monitoring
- Middle Green River

Overview

- Monitoring plan should generally include:

    1) 1-2 years of pre-project surveys (minimum) to establish baseline conditions
    2) Identification of a consistent set of parameters to be measured using same intensity and protocols in pre- and post-project surveys
    3) Survey protocol for each parameter that provides a statistically defensible method for evaluating and minimizing observer bias

After Green, R.H. 1979 Sampling design and statistical analysis methods for environmental biologists. John Wiley and Sons, Toronto, Ontario. 257 p.

Overview

- Reach Scale Monitoring = measurement of a limited set of key parameters intended to track trends in habitat condition over time throughout the reach of interest as a result of the cumulative effect of multiple restoration/mitigation projects
- Site specific Monitoring = Intensive measurement of a detailed set of key and optional parameters in the immediate vicinity of specific mitigation/restoration projects intended to demonstrate changes in habitat conditions resulting from individual projects

Reach Scale Monitoring

- Reach scale, baseline habitat monitoring of the middle Green River will be initiated in 2001 as part of the Additional Water Storage Project
- Numerous other restoration projects are planned for future implementation in the middle Green River
- Data gathered during AWSP habitat surveys will be available to other entities undertaking habitat restoration projects in the basin
- Input on monitoring approach and study plan is being solicited to ensure that data collected are useful to those entities

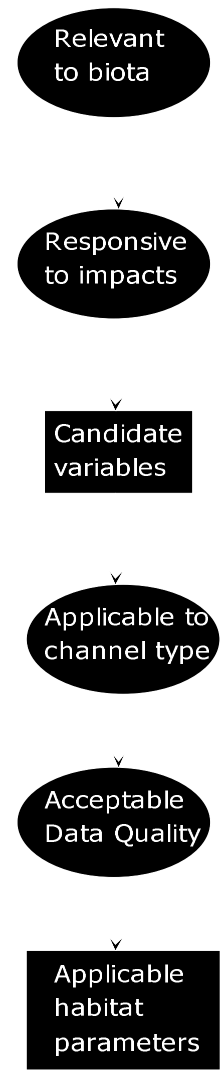
Reach Scale Monitoring

AWSP baseline habitat monitoring plan developed by:

1) Reviewing commonly used assessment and monitoring protocols (Attachments 1 & 2)

2) Identifying key monitoring parameters that will be useful to all projects implemented in the Middle Green River (Attachment 3)

3) Identifying additional parameters required to address specific AWSP concerns

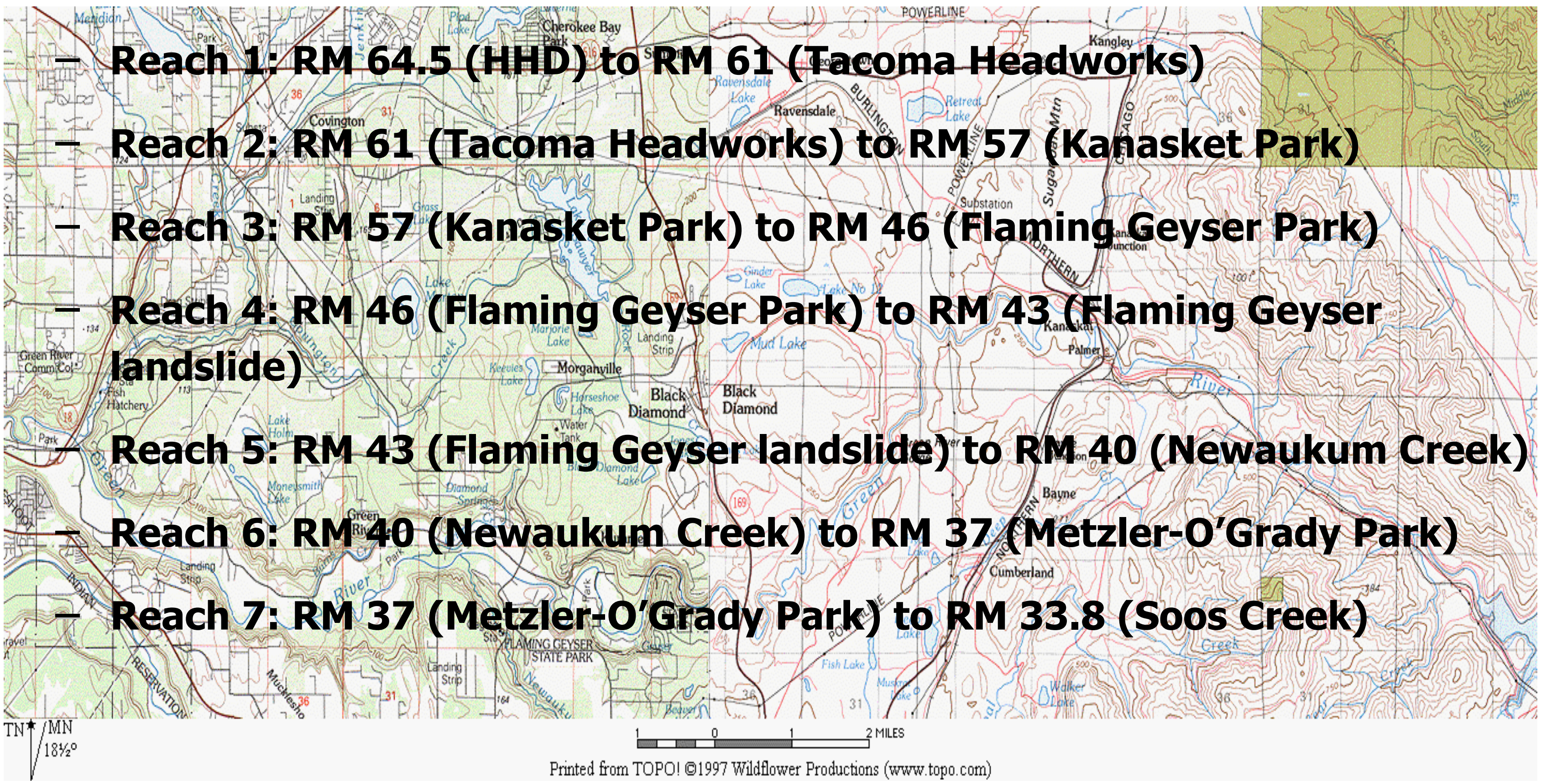


Reach Scale Monitoring

- The AWSP and associated restoration/mitigation programs influence the entire survey reach
- Key parameters evaluated through ground-based sampling of the entire survey reach
- Additional parameters evaluated in detailed surveys of 1000 foot long segments

Reach Scale Monitoring

- Survey Reach extends from RM 64.5 (HHD) to RM 33.8 (Soos Creek)
- Survey Reach will be stratified based on channel type/landuse factors as follows:
  - **Reach 1: RM 64.5 (HHD) to RM 61 (Tacoma Headworks)**
  - **Reach 2: RM 61 (Tacoma Headworks) to RM 57 (Kanasket Park)**
  - **Reach 3: RM 57 (Kanasket Park) to RM 46 (Flaming Geyser Park)**
  - **Reach 4: RM 46 (Flaming Geyser Park) to RM 43 (Flaming Geyser landslide)**
  - **Reach 5: RM 43 (Flaming Geyser landslide) to RM 40 (Newaukum Creek)**
  - **Reach 6: RM 40 (Newaukum Creek) to RM 37 (Metzler-O'Grady Park)**
  - **Reach 7: RM 37 (Metzler-O'Grady Park) to RM 33.8 (Soos Creek)**



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Reach Scale Monitoring

Parameters considered:

Channel	Banks	Habitat	LWD	Substrate	Riparian
Inter-terrace width	% eroding	Habitat units type	# of qualifying pieces	Dominant substrate size by unit	Vegetation type
Terrace height	Composition	Habitat unit length	# of functional pieces	Subdominant substrate size by unit	Age
Gradient	length/location of hydromodified banks	Habitat unit area	# of key pieces	Particle size distribution	Riparian buffer width
Discharge	Undercut length	Pool formative factor	# of LWD jams	Embeddedness	Canopy cover/ shade
Bankfull width	Undercut depth	Pool quality	LWD length	Percent surface fines	LWD recruitment
Bankfull depth	Slope	Maximum pool depth	LWD diameter	Percent fines-volumetric/weight	Species, size and position of riparian trees
Floodprone width		Riffle crest depth	LWD stability	Location and area of suitable spawning gravel patches	# of conifers
Floodprone depth		Residual depth	LWD species	Gravel - % area	
Wetted width		Pocket pool frequency	LWD condition	Silt/Sand/ Organics - % area	
Wetted depth		# pools > 1m deep	LWD volume	Spawning gravel scour	
Cross-section		Cover	LWD complexity rating	Boulder count	
Disturbances		Step-pool total		Q*	
Photographs		Qualitative Habitat Index (QHI)			
Location of physical barriers		V*			
Height of physical barriers					
# Road crossings					
# of Stormwater outfalls					

Reach Scale Monitoring

Habitat evaluation procedures that contain metrics for which quantitative criteria have been developed to assess channel condition.

Metric	NMFS 1999	WFPB 1997	ODFW 1997	May 1996	B.C. WRP 1985
Pools					
Length		x		x	x
Area			x	x	
Frequency	x	x	x	x	x
Depth			x		
Wood cover		x	x		x
Cover				x	
LWD					
Frequency (total)	x	x	x	x	x
Volume			x		
# key pieces		x	x	x	x
Channel					
W/D ratio	x		x		
Bank stability (% eroding)	x				
Substrate					
Embeddedness	x				
% fines		x		x	
Gravel (% area)			x		
Silt sand (% area)			x		
D_{10}				x	
Boulder cover					x
Riparian					
Shade (% cover)			x		
Frequency of large conifers in RMZ			x		

Reach Scale Monitoring

- Recommended Key Monitoring Parameters:
  - Bankfull width
  - Location/type of hydromodified banks
  - Habitat unit type
  - Pool length
  - Pool width
  - Maximum pool depth
  - Residual pool depth
  - # Qualifying pieces of LWD
  - # of Key sized pieces of LWD
  - # of Debris jams
  - Riffle particle size distribution
  - Shade

- Additional parameters to be measured under AWSP:
  - Level II Habitat unit type
  - Pool formative factor
  - Presence/Absence of Rootwad on key size LWD
  - Debris jam type
  - Spawning gravel availability
  - % Surface Fines
  - Low Flow barriers

Reach Scale Monitoring

General Measurement Standards:

- Locate reach endpoints using GPS
- Record flow daily
- Establish permanent photo point every 1000m
- Record equipment used to conduct survey
- Record parameters measured, definitions and data standards
- Record measurement units

Reach Scale Monitoring

Quality Assurance/Quality Control

- Calibrate tapes and rangefinders prior to survey and at least once per week during surveys
- Estimate then measure the length and diameter of 50 pieces of wood at the start of each survey and continue to measure and estimate until estimates and measurements vary by less than 10%
- Re-measure at least 3 pools per reach to evaluate measurement error

Site Specific Monitoring

- Types of site specific restoration/mitigation projects to be implemented under the AWSP and Green Duwamish River Basin Ecosystem Restoration Project:
  - LWD placement
  - Engineered log jams
  - Side channel reconnection
  - Removal of barrier culverts

Site Specific Monitoring

Watershed Restoration Program
Inspection and Monitoring

(after Gaboury and Wong 1999)

Inspection	Routine Evaluation	Intensive Evaluation
Inspect project to ensure compliance with design and permits	*Assess the confirmation, condition and functionality of individual project*	*Validate assumptions and assess relative effectiveness of project at meeting restoration objective*

All Projects → *Few Projects*

Site Specific Monitoring

- Identify key parameters relevant to all restoration projects to guide routine monitoring
- Incorporate pre-project monitoring into project design phase
- Establish schedule for routine post-project monitoring
- Work with researchers to develop intensive monitoring plans for representative site-specific

Site Specific Monitoring

Same as Reach Scale:

- Bankfull width
- Location/type of hydromodified banks
- Habitat unit type
- Pool length
- Pool width
- Maximum pool depth
- Residual pool depth
- # Qualifying pieces of LWD
- # of Key sized pieces of LWD
- # of Debris jams
- Riffle particle size distribution

Plus:

- Longitudinal profile
- Non-pool habitat lengths
- Non-pool habitat widths
- Bank composition
- LWD surveys according to Level II TFW protocols
- Particle size distribution in each riffle (Wolman pebble count)
- Spawning gravel availability according to TFW transect protocol
- Riparian community type

Site Specific Monitoring

General Measurement Standards

- Survey reach should extend 50 m upstream of project site and 7 to 10 bankfull widths downstream of the project site
- Establish permanent reference points according to TFW protocols
- Establish permanent photo point every 100m
- Record bankfull width every 100m
- Map riparian and bank composition, habitat units, suitable spawning gravel, LWD and other important features through out survey reach
- Development and implement suitable QA/QC procedures

Site Specific Monitoring

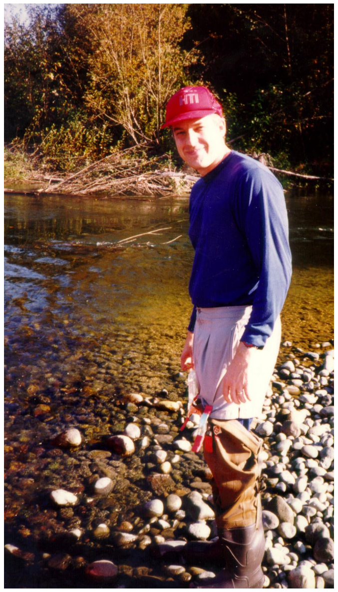
- Additional optional parameters specific to each site should be identified based on project goals and objectives
- Resources for identification of optional parameters:

"DRAFT- Monitoring Salmon Habitat in the Pacific Northwest" *available at:*
http://www.wa.gov/wdfw/hab/sshiap/dataptcl.htm

"DRAFT-Report to the Salmon Recovery Funding Board on the Engineered Log Jam Workshop"
available at: http://www.wa.gov/iac/srfbdocuments.html

"A framework for conducting effectiveness evaluations of watershed restoration projects"
available at: http://www.elp.gov.bc.ca/frco/bookshop/tech.htm

Workshop Goals Achieved



- Better understanding of other players and restoration activities
- List of reach scale monitoring parameters to be measured in the mainstem middle Green River on a repeated basis
- List of site-specific monitoring parameters for consideration when planning restoration projects
- Meeting summary and attendee list will be distributed via e-mail

APPENDIX B

Field Forms

Mainstem Green River Habitat Monitoring

Bankfull Width and Canopy Cover

Date: ____________________

Crew: ____________________

Reach: ____________________

Equipment:

Units:

Flow

			Canopy Cover				Location		
Distance	Bankfull Width (m)	Wetted Width (m)	1	2	3	4	Lat.	Long.	Comments

Mainstem Green River Habitat Monitoring

Pool Habitat Units

Date:______________________________

Crew:______________________________

Reach:______________________________

Equipment:

Units:

Flow

Pool Number	Length (m)	Width (m)	Maximum Pool Depth (m)	Pool Control Depth (m)	Pool Type	Pool Forming Factor	Spawning Gravel at pool tailout (Dimensions)	Pool Location Lat.	Long.	Comments

Pool Type:		**Pool Forming Factor**	
D	Dammed	LOG	Log
BW	Backwater	RW	Rootwad
LS	Lateral Scour	JAM	Jam
T	Trench	ROOT	Roots
MCS	Mid-channel scour	BLD	Boulder
P	Plunge	BDR	Bedrock
US	Underscour	BF	Bedform
E	Eddy	RR	Rip-rap
CON	Convergence	BEAV	Beaver Dam
		O	Other

Mainstem Green River Habitat Monitoring

Large Woody Debris

Date: ______________________

Crew: ______________________ · = intact

Reach: ______________________ + = cut end

Equipment:

Units:

Flow

Medium log (30-50mm)	**Medium log w/Rootwad**	**Large Log (50-85mm)**	**Large Log w/ rootwad**	**Key Piece (>85 mm)**	**Key Piece w/rootwad**	**Rootwad**	**Small jam (10-50 pieces)**	**Medium jam (50-100 pieces)**	**Large jam (>100 pieces)**

Wood Calibration

	Estimated Width	Estimated Length	Estimated Width	Estimated Length	Measured Width	Measured Length
1						
2						
3						
4						
5						

6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

Mainstem Green River Habitat Monitoring

Pebble Count

Date: ____________________

Crew: ____________________

Reach: ____________________

Equipment: ____________________

Units: ____________________

Flow ____________________

Location Photo#

1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Location Photo#

1					
2					
3					
4					
5					
6					
7					
8					

9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Mainstem Green River Habitat Monitoring

Date:______________________________________
Crew:______________________________________
Reach:______________________________________

Low Flow Barriers

Location	Depth	Length	Gradient	Photo #	Comments

Passage Obstructions

Location	Height	Length	Gradient	Photo #	Comments

APPENDIX C

Reach Data

Green River Baseline Habitat Monitoring

Pool Habitat

Reach # **1**
Rm Start **61.5**
Rm End **64.5**
Length (m): **4,828**

Pool #	Length (m)	Average Width (m)	Width (m)								Area (m^2)	Max. Pool Depth (m)	Pool Control Depth (m)	Residual Pool Depth (m)	Pool Type	Pool Forming Factor
R1P1	32	18.0	22	18	14						576			0	Plunge	HHD outflow
R1P2	58	29.3	32	32	24						1701.3333	5.3	1.1	4.2	Lateral Scour/plunge	Bedrock
R1P3	39	25.0	24	28	24	24					975	4.1	1.6	2.5		Bedrock
R1P4	66	23.0	22	18	26	26					1518	3	1.6	1.4	Lateral Scour	Rip-rap from road
R1P5	102	16.0	14	14	8	20	20	18	18		1632	7.4	1.6	5.8	Trench	Bedrock
R1P6	252	14.9	18	14	14	14	24	14	6	10	3744	5	1	4	Trench	Bedrock
R1P7	210	26.9	18	20	22	26	30	40	32	24	5640	5.7	0.7	5	Trench	Bedrock
R1P8	44	12.4	18	18	18	6	2				545.6	2.1	0.8	1.3	Lateral Scour	Bedrock
R1P9	50	30.0	26	32	32						1500	1.8	0.9	0.9	Lateral scour	Meander
R1P10	136	19.3	26	30	22	9	22	22	4		2622.8571	2.7	0.55	2.15	Lateral scour	Rip-rap/bedrock
R1P11																Headworks dam
Total	989										20,455					
Average	98.9	21.5									2,045.5	4.1	1.1	2.7		
Std Dev	77.0	6.2									1,583.2	1.9	0.4	1.9		

Green River Baseline Habitat Monitoring

Pool Habitat

Reach #	**2**
Rm Start	**57**
Rm End	**61.5**
Length (m):	**7,242**

Pool #	Length (m)	Average Width (m)	Width (m)									Area (m^2)	Max. Pool Depth (m)	Pool Control Depth (m)	Residual Pool Depth (m)	Pool Type	Pool Forming Factor
R2P1	82	22.5	24	22	22	22						1845	4	0.8	3.2	Trench	Bedrock
R2P2	242	18.0	18	12	18	18	16	22	22	18		4356	4.25	0.8	3.45	Trench	Bedrock
R2P3	234	26.0	28	30	26	22	22	28				6084	4.05	1	3.05	Trench	Bedrock
R2P4	100	29.0	27	32	28							2900	4.55	0.3	4.25	Lateral Scour	Bedrock/Rip-rap
R2P5	84	30.0	54	22	22	32	30	20				2520	5.4	0.4	5	Lateral Scour	Bedrock
R2P6	134	28.3	24	24	32	32	26	32				3796.6667	3.3	0.8	2.5	Lateral Scour	Ecology blocks(photo)
R2P7	80	23.2	12	22	26	30	26					1856	2.5	0.6	1.9	Midscour	Confluence
R2P8	62	23.6	22	22	26	26	22					1463.2	2.25	1.1	1.15	Trench	Bedrock
R2P9	90	33.7	34	36	36	34	32	30	34	26		2947.5	4.9	0.85	4.05	Lateral Scour	Bedrock
R2P10	248	23.4	18	18	32	22	18	26	30	26	36	6227.5556	4.55	1.2	3.35	Trench	Bedrock
R2P11	40	19.6	16	26	22	20	14					784	2	0.8	1.2	Plunge	Bedrock ledge
R2P12	70	14.9	10	12	14	18	18	18	14			1040	3.35	1.7	1.65	Trench	Bedrock
R2P13	126	22.6	18	22	22	30	22	22	22	26		2898	2.9	0.7	2.2	Lateral Scour	Bedrock
R2P14	144	24.3	32	30	24	22	22	22	18	24		3492	2.9	0.5	2.4	Lateral Scour	Bedrock
R2P15	104	24.4	18	32	36	18	18					2537.6	3.45	0.7	2.75	Lateral Scour	Bedform/bedrock
R2P16	66	34.3	16	20	22	52	48	48				2266	6.3	0.65	5.65	Lateral Scour	Bedrock
Total	1,906											47,014					
Average	462.6	24.9										2,938.3	3.8	0.8	3.0		
Std Dev	66.4	5.3										1,577.9	1.2	0.3	1.3		

Green River Baseline Habitat Monitoring

Pool Habitat

Reach #	**3**
Rm Start	**45**
Rm End	**57**
Length (m):	**19,311**

Pool #	Length (m)	Average Width (m)	Width (m)						Area (m^2)	Max. Pool Depth (m)	Pool Control Depth (m)	Residual Pool Depth (m)	Pool Type	Pool Forming Factor
R3P1	87	29.0	22	32	32	30			2,523	3.45	0.3	3.15	Trench	Bedrock
R3P2	54	23.0	22	24	28	18			1,242	2.8	0.8	2	Trench	Bld/Bedrock
R3P3	56	21.5	18	22	22	24			1,204	3.3	0.8	2.5		
R3P4	36	22.0	19	19	28				792	2.7	0.7	2	Lat. scour	Bedrock
R3P5	214	25.3	22	24	30				5,421	5.9	0.9	5	Trench	Bedrock
R3P6	76	32.5	22	34	38	36			2,470	3.5	0.5	3	Trench	Bedrock
R3P7	92	39.5	36	40	46	36			3,634		0.6			
R3P8	140	21.0	14	18	24	22	22	26	2,940	7.4	0.5	6.9	Trench	Bedrock
R3P9	68	32.0	32	36	28	32			2,176	4.5	0.55	3.95	Trench	Bedrock
R3P10	132	32.3	30	14	18	26	44	62	4,268	4.7	0.8	3.9	Trench	Bedrock
R3P11	56	22.4	16	18	24	32	22		1,254	4	0.7	3.3	Trench	Bedrock
R3P12	45	18.0	18	18	18	14	22		810	2.6	1.4	1.2	Trench	Bedrock
R3P13	22	16.0	18	14					352	1.8	0.5	1.3	Backwater	Bedrock
R3P14	130	19.3	18	22	24	16	18	18	2,513	4.4	1.15	3.25	Trench	Bedrock
R3P15	136	23.0	20	26	24	22			3,128	5.4	0.7	4.7	Trench	Bedrock
R3P16	48	16.0	14	18	16				768	3.8	0.8	3	Trench	Bedrock
R3P17	37	22.7	24	22	22				839	3.3	0.8	2.5	Trench	Bedrock
R3P18	91	23.5	22	22	22	28			2,139	3.4	1.4	2	Trench	Bedrock
R3P19	22	19.3	18	22	18				425	2.3	0.65	1.65	Trench	Bedrock
R3P20	22	23.3	18	22	30				513	2.7	0.8	1.9	Trench	Boulder
R3P21	52	15.0	5	17	20	18			780	5	1	4	Trench	Boulder
R3P22	38	20.5	22	14	24	22			779	2.8	1.5	1.3	Trench	Bedrock
R3P23	288	15.5	**16**	21	21	10	12	13	4,464	3	0.8	2.2	Trench	Bedrock
R3P24	58	32.0	32						1,856	3.7	0.7	3	Trench	Bedrock/boulder
R3P25	88	26.0	24	22	18	24	40	28	2,288	4.7	1.1	3.6	Trench	Bedrock

Green River Baseline Habitat Monitoring (cont)

Pool Habitat

Reach # **3**
Rm Start **45**
Rm End **57**

Length (m): **19,311**

Pool #	Length (m)	Average Width (m)	Width (m)						Area (m^2)	Max. Pool Depth (m)	Pool Control Depth (m)	Residual Pool Depth (m)	Pool Type	Pool Forming Factor
R3P26	55	28.5	30	32	22	30			1,568	2.8	0.9	1.9	Trench	Bedrock
R3P27	214	21.7	24	24	14	22	24	22	4,637	3.9	0.7	3.2	Trench	Bedrock
R3P28	100	26.0	18	28	32				2,600	4	0.6	3.4	Trench	Bedrock
R3P29	148	34.3	28	30	42	42	36	28	5,081	5.5	0.9	4.6	Lat. scour	Meander bend/boulder
R3P30	116	23.0	24	22	28	22	18	24	2,668	5	1	4	Trench	Bedrock
R3P31	50	20.0	20						1,000	3	1	2	Trench	Bedrock
R3P32	132	10.8	12	9	14	10	10	10	1,430	5	3	2	Trench	Bedrock
R3P33	58	13.5	12	14	14	14			783	3.3	1.1	2.2	Trench	Bedrock
R3P34	**70**	30.7	34	30	28				2,147	3	0.6	2.4	Lateral/Trench	Boulder
R3P35	50	22.3	14	30	23				1,117	4	0.7	3.3	Plunge/ Trench	Bedrock/boulder
R3P36	78	17.2	14	14	14	22	22		1,342	4	0.9	3.1	Trench	Bedrock
R3P37	135	17.7	20	18	18	18	18	14	2,385	4	0.9	3.1	Trench	Bedrock
R3P38	72	24.0	20	24	24	28			1,728	3.3	0.8	2.5	Lateral scour	Bedrock
R3P39	154	24.6	22	32	21	28	20		3,788	4.5	0.7	3.8	Lateral scour	Bedrock
R3P40	42	14.0	14	14	14				588	2	0.7	1.3	Lateral scour	Meander bedform
R3P41	46	20.7	18	22	22				951	2.8	0.9	1.9	Lateral scour	Bedform
R3P42	78	21.0	20	16	24	24			1,638	4	0.5	3.5	Lateral scour	Bedrock
R3P43	126	30.5	18	28	42	34			3,843	6.6	0.25	6.35	Lateral scour	Bedrock
R3P44	64	24.0	28	22	22	24			1,536	3.6	0.7	2.9	Lateral scour	Bedrock
R3P45	60	21.7	20	22	24	22	20	22	1,300	3.2	0.7	2.5	Lateral scour	Bedrock
R3P46	75	13.0	10	14	16	12			975	2.1	0.7	1.4	Lateral scour	Bedrock

Green River Baseline Habitat Monitoring (cont)

Pool Habitat

Reach #	**3**
Rm Start	**45**
Rm End	**57**
Length (m):	**19,311**

Pool #	Length (m)	Average Width (m)	Width (m)							Area (m^2)	Max. Pool Depth (m)	Pool Control Depth (m)	Residual Pool Depth (m)	Pool Type	Pool Forming Factor
R3P47	48	23.5	22	24	24	24				1,128	2.8	0.8	2	Boulder scour	Boulder
R3P48	86	24.5	22	24	26	26				2,107	2.3	1.1	1.2	Center/lateral scour	Bedrock
R3P49	54	32.0	32	34	30					1,728	2.8	0.8	2	Center scour/plunge	Boulder
R3P50	114	26.0	32	32	28	24	18	22		2,964	2.2	1.2	1	Lateral scour/plunge	Bedform/meander bend
R3P51	76	16.5	14	16	22	14				1,254	3.5	0.7	2.8	Lateral scour	Bedrock
R3P52	102	32.5	38	40	26	26				3,315	1.8	0.4	1.4	Lateral scour	Bedrock
R3P53	146	22.4	16	22	16	26	32			3,270	4.1	0.5	3.6	Trench	Bedrock
R3P54	116	26.0	26	26	32	28	18			3,016	3.6	0.6	3	Lateral scour	Bedrock/bldr
R3P55	124	20.6	14	16	18	24	20	24	28	2,551	2.7	0.5	2.2	Trench	Bedrock
Total	43,709									114,016					
Average	693.8	23.2								2,073.0	3.6	0.8	2.8		
Std Dev	3,398.5	6.0								1,266.0	1.2	0.4	1.2		

Green River Baseline Habitat Monitoring

Pool Habitat

Reach # **4**
Rm Start **40.8**
Rm End **45**
Length (m): **6,759**

Pool #	Length (m)	Average Width (m)	Width (m)							Area (m^2)	Maximum Pool Depth (m)	Pool Control Depth	Residual Pool Depth	Pool Type	Pool Forming Factor
R4P1	28	16.7	20	14	16					467	2.4	0.8	1.6	Lat. Scour	Bedrock
R4P2	132	25.1	18	22	22	22	28	28	36	3,319	3.5	0.55	2.95	Lat. Scour	Bedrock
R4P3	64	14.8	14	14	14	14	18			947	5.7	0.85	4.85	Lat. Scour	Bedrock
R4P4	100	22.0	18	18	20	36	18			2,200	2	0.4	1.6	Lat. Scour	Bedrock
R4P5	126	16.4	12	14	22	20	14			2,066	2.5	0.8	1.7	Lat. Scour	Bedrock
Total	450									8,999					
Average	90.0	19.0								1,799.8	3.2	0.7	2.5		
Std Dev	43.8	4.4								1,122.8	1.5	0.2	1.4		

Green River Baseline Habitat Monitoring

Pool Habitat

Reach # **5**
Rm Start **38**
Rm End **40.8**
Length (m): **4,506**

Pool #	Length (m)	Average Width (m)	Width (m)							Area (m^2)	Max. Pool Depth (m)	Pool Control Depth (m)	Residual Pool Depth (m)	Pool Type	Pool Forming Factor
R5P1	124	18.4	20	22	20	16	14			2,282	1.4	0.5	0.9	Lateral scour	Bedrock
R5P2	46	12.8	9	14	16	12				587	1.25	0.3	0.95	Lateral scour	First Bedform/LWD
R5P3	118	21.6	22	22	22	24	18			2,549	1.3	0.3	1	Lateral scour	Confluence w/ MOAS
R5P4	244	22.0	24	22	22	20	22			5,368	1.8	0.4	1.4	Lateral scour	Bedform
R5P5	76	13.6	14	14	14	14	12			1,034	1.5e	0.7	0.8	Lateral scour	Bedform/LWD
R5P6	130	16.8	16	14	14	22	18			2,184	1.9	0.6	1.3	Lateral scour	Bedform/LWD
R5P7	132	16.0	14	14	14	14	16	18	22	2,112	2.05	0.45	1.6	Lateral scour	Bedform
R5P8	58	19.0	22	18	18	18				1,102	3.4	0.55	2.85	Underscour	Woodformed- jammed
R5P9	64	24.0	32	16	24					1,536	2.8	0.65	2.15	Underscour	Woodformed- jammed
R5P10	68	27.0	28	24	22	34				1,836	3.85	0.4	3.45	Underscour	Woodformed- jammed
Total	1,060									20,589					
Average	106.0	19.1								2,058.9	2.2	0.5	1.6		
Std Dev	58.5	4.6								1,321.5	0.9	0.1	0.9		

Green River Baseline Habitat Monitoring

Pool Habitat

Reach # **6**
Rm Start **32**
Rm End **38**
Length (m): **9,656**

Pool #	Length (m)	Average Width (m)	Width (m)							Area (m²)	Maximum Pool Depth (m)	Pool Control Depth	Residual Pool Depth	Pool Type	Pool Forming Factor
R6P1	214	20.0	24	22	22	18	18	16		4,280		0.65		Lat. Scour	Rip-rap
R6P2	140	16.7	9	16	22	16	18	22	14	2,340	3.75	0.7	3.05	Lat. Scour	Bedrock
R6P3	102	13.2	10	16	14	14	12			1,346		0.65		Lat. Scour	Bedform/rip-rap
R6P4	266	14.6	36	8	3	18	14	12	11	3,876	2.9	1	1.9		
R6P5	162	19.6	22	24	24	14	14			3,175	2.6	0.7	1.9	Lat. Scour	Rip-rap
R6P6	24	11.3	12	12	10					272	2.2	0.5	1.7	Lat. Scour	LWD
R6P7	24	14.0	14	12	16					336	1.9	0.6	1.3	Underscour	wood-small jam
R6P8	128	20.5	14	20	22	26				2,624	1.7	0.5	1.2	Center scour	Confluence
R6P9	82	14.7	12	14	18					1,203	2	0.6	1.4	Lat. Scour	Bedrock/clay
R6P10	126	18.4	18	16	14	22	22			2,318	3.55	0.6	2.95	Lat. Scour	Bedrock
R6P11	138	19.5	16	20	20	22				2,691	2.45	0.7	1.75	Lat. Scour	Rip-rap
R6P12	206	16.7	14	18	18					3,433	2.5	1.1	1.4	Lat. Scour	Rip-rap
R6P13	60	12.5	12	12	12	14				750	2.05	0.65	1.4	Lat. Scour	Log jam
R6P14	114	15.6	12	10	16	18	22			1,778	2.3	0.95	1.35	Lat. Scour	Bedrock
R6P15	94	24.5	14	28	34	22				2,303	3.4	1	2.4	Center scour	Confluence
R6P16	198	25.6	30	34	22	22	20			5,069	2.7	0.75	1.95	Trench	Bedform
R6P17	42	13.3	12	14	14					560	2.2	0.9	1.3	Lat. Scour	LWD
R6P18	78	25.0	20	24	22	34				1,950	5.3	1	4.3	Lat. Scour	Rip-rap
Total	2,198									40,305					
Average	122.1	17.5								2,239.2	2.7	0.8	2.0		
Std Dev	68.0	4.4								1,376.7	0.9	0.2	0.8		

Reach # 1
Length: RM 61-64.5

Distance	Wetted Width	Bankfull Width	Canopy				Average Shade	Comments
0	26	31	3	5	13	9	7.8	
1000	40	43	0	0	9	7	4.16	
2000	34	42	0	1	5	12	4.68	
3000	18	24	3	4	8	19	8.84	
4000	28	34	2	2	10	12	6.76	
5000	42	44	1	1	10	6	4.68	Some location as pool 2 tail
6000	24	28	1	3	12	6	5.72	
7000	30	39	2	38	6	30	19.76	
8000	18	20						
9000	20	30	47	31	2	4	21.84	
10000	22	30	5	54	8	24	23.66	
11000	30	34	1	38	3	24	17.16	
12000	32	34	4	21	0	35	15.6	
13000	22	34	33	10	14	2	15.34	Canopy data taken 25 ft. u/s on BR ledge
14000	22	32	4	17	4	23	12.48	
	27.2	33.26667				15.21429		

Reach # 2
Length: RM 57-61

Distance	Wetted Width	Bankfull Width	Canopy				Average Shade	Comments
0	15	26	63	18	27	49	40.82	
1000	30	36	0	21	12	67	26	
2000	48	52	1	42	2	0	11.7	
3000	28	38	1	24	0	17	10.92	
4000	44	50	3	46	4	0	13.78	
5000	26	44	0	40	0	10	13	
6000	40	48	3	54	2	5	16.64	
7000	40	44	0	16	1	28	11.7	
8000	32	44	2	14	17	2	9.1	
9000	30	34	0	37	0	7	11.44	
10000	32	36	4	43	0	18	16.9	
11000	26	44	11	4	0	35	13	
12000	36	40	36	8	12	7	16.38	
13000	26	28	7	60	4	21	23.92	
14000	22	52	16	19	9	14	15.08	
15000	36	38	39	4	28	8	20.54	
	31.9375	40.875					16.9325	

Reach # 3
Length: RM 45-57

Distance	Wetted Width	Bankfull Width	Canopy				Average Shade	Comments
0	5	42	17	34	1	1	13.78	
1000	6.5	42	8	29	19	35	23.66	
2000	28	42	0	53	0	38	23.66	
3000	24	36	1	1	0	32	8.84	
4000	52	54	0	13	14	0	7.02	
5000	22	42	0	2	19	9	7.8	BS rapid with lots of swimmers
6000	24	28	0	69	18	2	23.14	
7000	34	38	8	10	26	0	11.44	
8000	34	37	24	47	19	44	34.84	
9000	16	22	Current too fast					
10000	18	44	4	9	35	7	14.3	
11000	32	50	0	27	14	46	22.62	
12000	18	32	35	28	36	78	46.02	
13000	16	36	26	46	9	76	40.82	
14000	29	42	5	36	0	45	22.36	
15000	22	32	19	38	9	48	29.64	
16000	18	24	14	38	45	7	27.04	
17000	42	50	1	37	9	22	17.94	
18000	42	34	12	21	1	27	15.86	
19000	16	30	17	32	27	67	37.18	
20000	22	28	11	14	86	38	38.74	
21000	24	22	3	24	39	18	21.84	
22000	32	40	22	37	11	36	27.56	
23000	22	32	5	36	58	6	27.3	
24000	30	42	3	8	60	9	20.8	
25000	30	44	7	32	38	0	20.02	
26000	18	22	1	47	52	18	30.68	
27000	28	58	2	9	3	30	11.44	
28000	22	36	9	44	9	59	31.46	
29000	24	32	8	43	9	56	30.16	
30000	42	50	7	30	19	84	36.4	
31000	18	44	11	72	58	12	39.78	
32000	14	36	15	47	45	67	45.24	
33000	28	32	28	72	24	27	39.26	
34000	22	18	24	45	24	88	47.06	
35000	14	22	20	68	35	68	49.66	
36000	26	36	8	54	13	62	35.62	
37000	32	40	5	25	3	39	18.72	
38000	32	36	8	26	56	96	48.36	
39000	34	42	2	12	0	26	10.4	
40000	20	32	24	14	27	43	28.08	
41000	24	28	39	10	21	73	37.18	
42000	24	48	0	36	28	7	18.46	
43000	24	40	13	41	42	12	28.08	

Reach # 3 (cont)
Length: RM 45-57

Distance	Wetted Width	Bankfull Width	Canopy				Average Shade	Comments
44000	24	26	10	4	43	13	18.2	
45000	32	54	5	43	12	17	20.02	
46000	60	64	2	22	9	12	11.7	
47000	28	40	7	44	14	64	33.54	
48000	32	48	10	37	6	43	24.96	
49000	46	50	0	44	1	20	16.9	
50000	28	36	17	74	89	26	53.56	
51000	24	32	18	72	28	56	45.24	Widths taken on island
52000	28	30	14	46	14	54	33.28	
53000	30	38	10	21	0	30	15.86	
54000	28	38	11	56	6	39	29.12	
55000	32	42	2	40	18	44	27.04	
56000	36	38	8	19	5	33	16.9	
57000	56	60	2	18	7	26	13.78	
58000	30	56	13	4	2	24	11.18	
59000	46	56	8	36	6	6	14.56	
60000	28	38	60	17	26	13	30.16	
	27.34677	38.7377					26.43767	

Reach # 4
Length: RM 40-45

Distance	Wetted Width	Bankfull Width	Canopy				Average Shade	Comments
0	30	38	3	60	9	19	23.66	
1000	46	52	0	19	1	32	13.52	
2000	38	42	17	27	2	62	28.08	
3000	36	40	14	42	3	52	28.86	
4000	24	38	13	28	4	76	31.46	
5000	28	44	12	26	6	16	15.6	
6000	34	38	0	14	0	12	6.76	
7000	36	42	0	6	0	15	5.46	
8000	38	46	0	0	0	15	3.9	
9000	18	30	45	3	36	76	41.6	Split channel-determined to be side channel(island above bank full)
10000	22	34	0	4	1	0	1.3	
11000	42	46	0	1	0	13	3.64	
12000	34	44	19	8	0	33	15.6	
13000	28	52	6	8	3	50	17.42	
14000	24	34	23	3	13	0	10.14	
15000	34	42	12	41	8	50	28.86	Beaver activity
16000	40	46	0	0	0	0	0	
17000	22	24	4	0	0	27	8.06	
18000	30	36	11	16	0	51	20.28	
19000	24	28	8	8	14	35	16.9	
	31.4	39.8					16.055	

Reach # 5
Length: RM 38-40.8

Distance	Wetted Width	Bankfull Width	Canopy				Average Shade	Comments
0	38	42	9	29	6	12	14.56	
1000	22	44	28	2	1	71	26.52	
2000	26	38	2	23	8	45	20.28	
3000	44	46	0	37	3	18	15.08	
4000	22	42	0	0	0	9	2.34	At mouth of MOAS
5000	20	42	1	19	3	0	5.98	
6000	16	54	0	0	0	0	0	
7000	22	40	5	0	14	3	5.72	Just above confluence of MOAS
8000	22	42	3	0	8	44	14.3	
9000	20	26	0	17	28	83	33.28	
10000	22	26	0	0	0	0	0	
11000	28	42	3	33	0	5	10.66	
12000	18	34	14	4	18	82	30.68	
	24.61538	39.84615					13.8	

Bankfull Widths

Reach # 6
Length: RM 32-38

Distance	Wetted Width	Bankfull Width	Canopy				Average Shade	Comments
0	15	20	0	4	5	33	10.92	
1000	38	50	13	4	2	60	20.54	
2000	38	55	1	1	0	56	15.08	
3000	32	46	0	5	0	15	5.2	
4000	42	48	0	3	1	25	7.54	
5000	16	30	4	50	0	52	27.56	
6000	42	64	1	10	3	19	8.58	
7000	28	38	14	20	4	28	17.16	
8000	34	38	4	2	0	31	9.62	
9000	20	56	0	14	4	0	4.68	
10000	22	42	0	42	0	25	17.42	
11000	43	58	0	16	0	21	9.62	
12000	36	40	0	1	0	14	3.9	
13000	30	36	0	40	0	21	15.86	
14000	16	60	11	3	3	0	4.42	
15000	38	56	1	3	4	55	16.38	
16000	28	50	1	25	1	0	7.02	
17000	28	32	16	0	0	17	8.58	
18000	18	48	1	0	3	33	9.62	
19000	24	42	23	8	0	0	8.06	
20000	48	52	24	0	4	4	8.32	
21000	38	50	16	5	8	66	24.7	
22000	34	38	0	23	1	21	11.7	
23000	22	52	51	15	5	2	18.98	
24000	22	42	24	2	4	6	9.36	
25000	32	34	5	13	55	10	21.58	
26000	16	36	15	82	29	2	33.28	
27000	38	40	0	0	27	55	21.32	
	29.92857	44.75					13.46429	

Middle Green River Habitat Monitoring 2001

Large Woody Debris

Reach # 1
Length RM 61-64.5

	Medium Log	Md Log w/rootwad	Large Log	Lg Log w/rootwad	Key Piece	Key Pc. w/ Rootwad	Rootwad	Small Jam	Medium Jam	Large Jam
Zone 1	4	3	0	0	2	0	0	0	0	0
Zone 2	8	1	0	0	0	0	0	0	0	0

Reach # 2
Length RM 57-61

	Medium Log	Md Log w/rootwad	Large Log	Lg Log w/rootwad	Key Piece	Key Pc. w/ Rootwad	Rootwad	Small Jam	Medium Jam	Large Jam
Zone 1	7	3	8	2	0	0	1	0	0	0
Zone 2	6	0	4	2	1	1	0	0	0	0

Reach # 3
Length RM 45-57

	Medium Log	Md Log w/rootwad	Large Log	Lg Log w/rootwad	Key Piece	Key Pc. w/ Rootwad	Rootwad	Small Jam	Medium Jam	Large Jam
Zone 1	**35**	**20**	**13**	**18**	**3**	**3**	**2**	**7**	**0**	**0**
Zone 2	30	11	15	6	4	1	3	1	0	0

Reach # 4
Length RM 40-45

	Medium Log	Md Log w/rootwad	Large Log	Lg Log w/rootwad	Key Piece	Key Pc. w/ Rootwad	Rootwad	Small Jam	Medium Jam	Large Jam
Zone 1	**13**	**7**	**0**	**2**	**4**	**0**	**1**	**5**	**0**	**0**
Zone 2	**2**	**2**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**

Reach # 5
Length RM 38-40.8

	Medium Log	Md Log w/rootwad	Large Log	Lg Log w/rootwad	Key Piece	Key Pc. w/ Rootwad	Rootwad	Small Jam	Medium Jam	Large Jam
Zone 1	**18**	**12**	**0**	**4**	**2**	**0**	**5**	**4**	**1**	**1**
Zone 2	**13**	**9**	**2**	**1**	**0**	**1**	**3**	**0**	**0**	**0**

Reach # 6
Length RM 32-38

	Medium Log	Md Log w/rootwad	Large Log	Lg Log w/rootwad	Key Piece	Key Pc w/ Root wad	Rootwad	Small Jam	Medium Jam	Large Jam
Zone 1	**23**	**29**	**2**	**17**	**0**	**1**	**21**	**4**	**0**	**1**
Zone 2	**9**	**10**	**5**	**7**	**1**	**1**	**5**	**0**	**0**	**0**

APPENDIX D

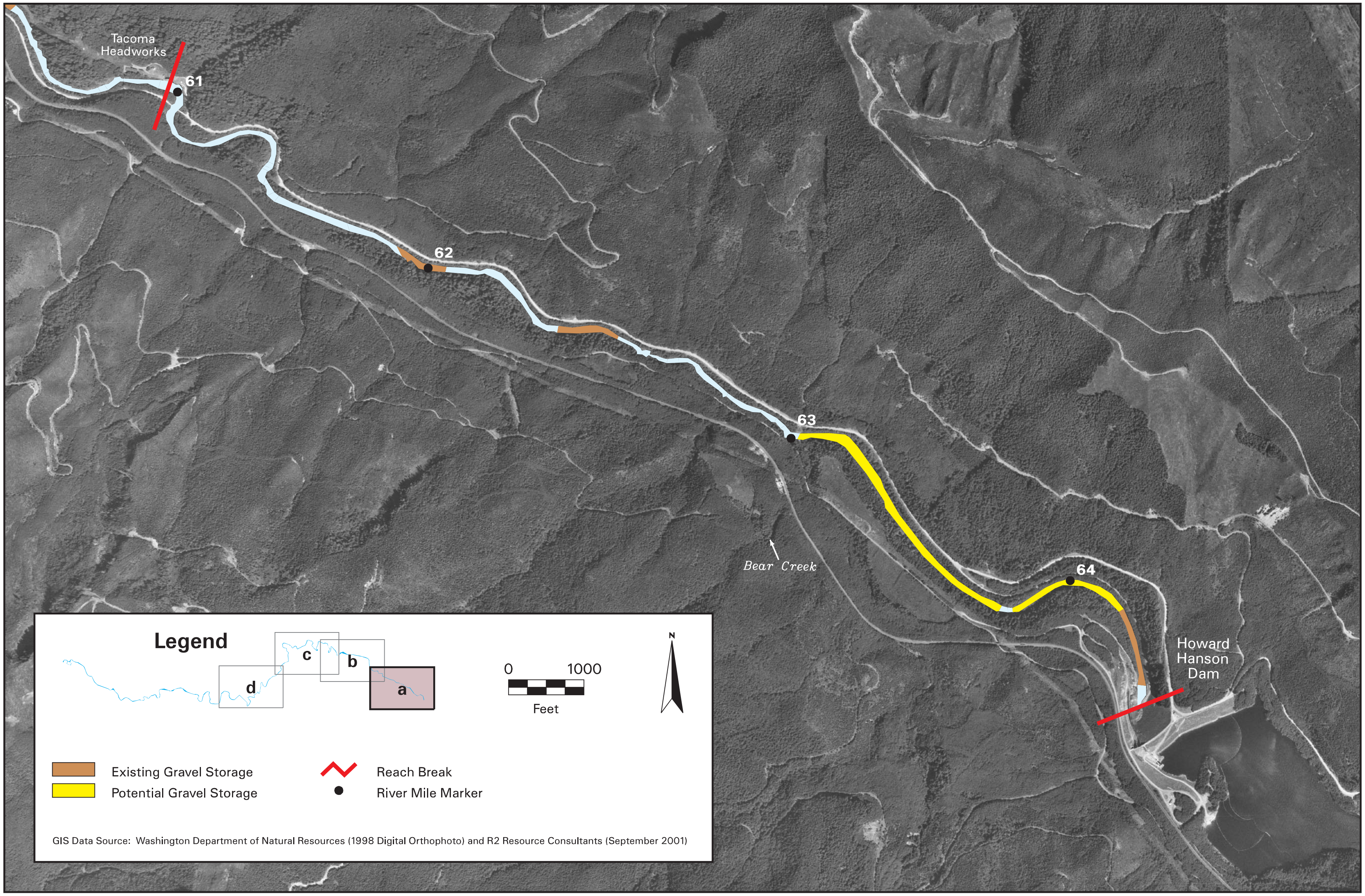
Existing and Potential Gravel Storage

Existing and Potential Gravel Storage

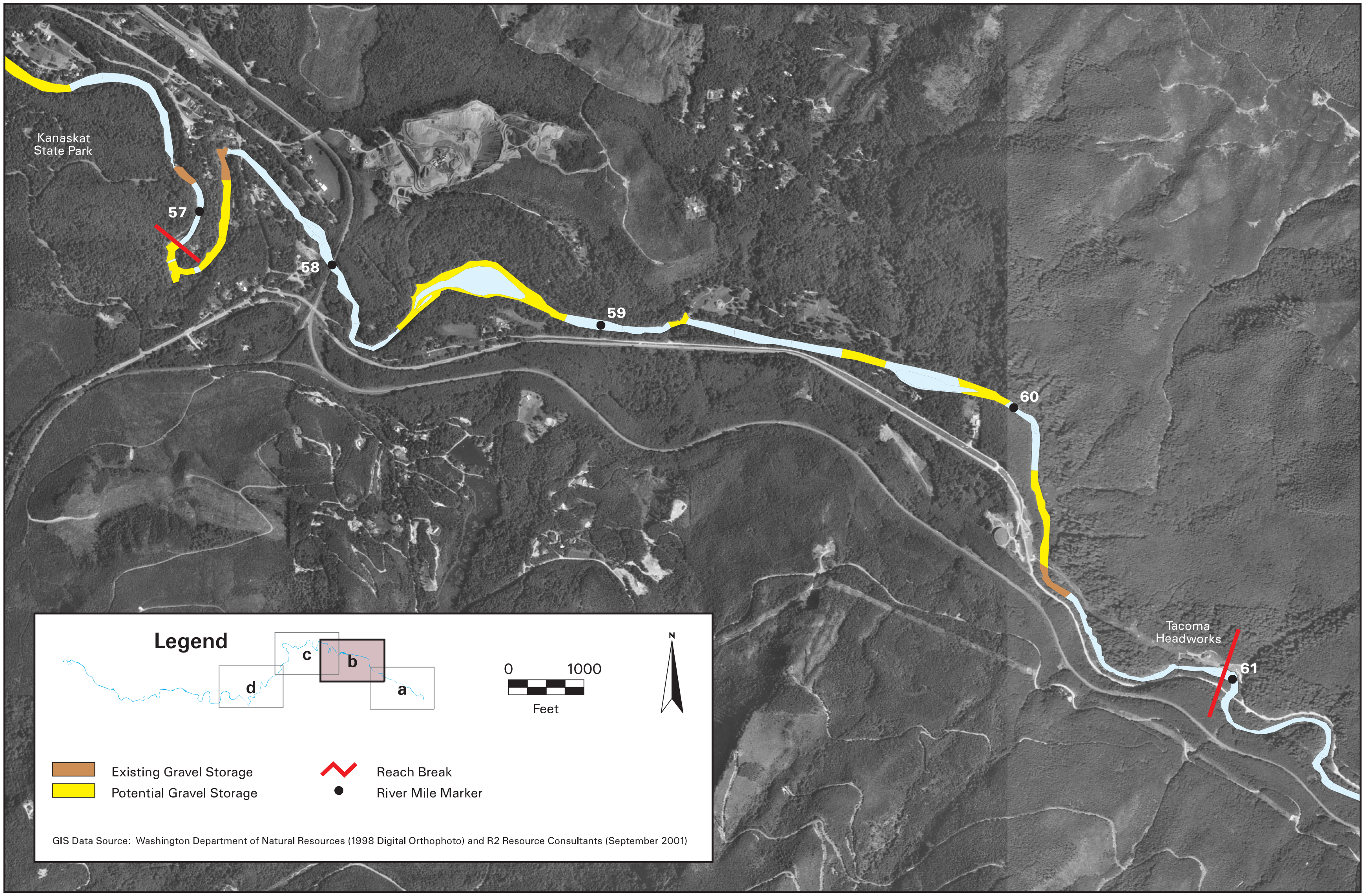
Construction of Howard Hanson Dam in 1961 has resulted in the trapping of bedload sediments from the upper Green River basin. This material was formerly routed downstream past the dam, replenishing storage sites in the middle Green River. Interruption of the bedload sediment supply is believed to have resulted in armoring and loss of spawning gravels in the middle Green River. In a recent geomorphic evaluation of the proposed gravel placement program, Perkins (1999) concluded that armoring may have affected Reaches 1, 2 and 3 (RM 64.5 to RM 47), but would not have affected Reaches 4 and 5 until 1997 at the earliest, and may currently be masked by recent large inputs form landslides in the vicinity of the Green River gorge. Our data support that conclusion: gravel deposits were rare in reaches 1 and 2, and the upper portion of Reach 3. Downstream of a large landslide located at RM 49 in Reach 3 gravel was abundant. The substrate in reaches 4 and 5 was predominantly gravel and cobble sized material.

Qualitative information on the location of existing and potential gravel storage sites in reaches 1, 2 and 3 was collected to guide future monitoring efforts. Under current conditions, most existing gravel deposits are located at the tailouts of large pools in these reaches. Pools where tailout gravel deposits were noted and other gravel storage locations are depicted on Maps a to d. Highlighted map units include the entire pool feature; however, tailout deposits generally occupied only the downstream-most portion of the pool. No attempt was made to quantify the volume of gravel deposits at pool tailouts or other locations.

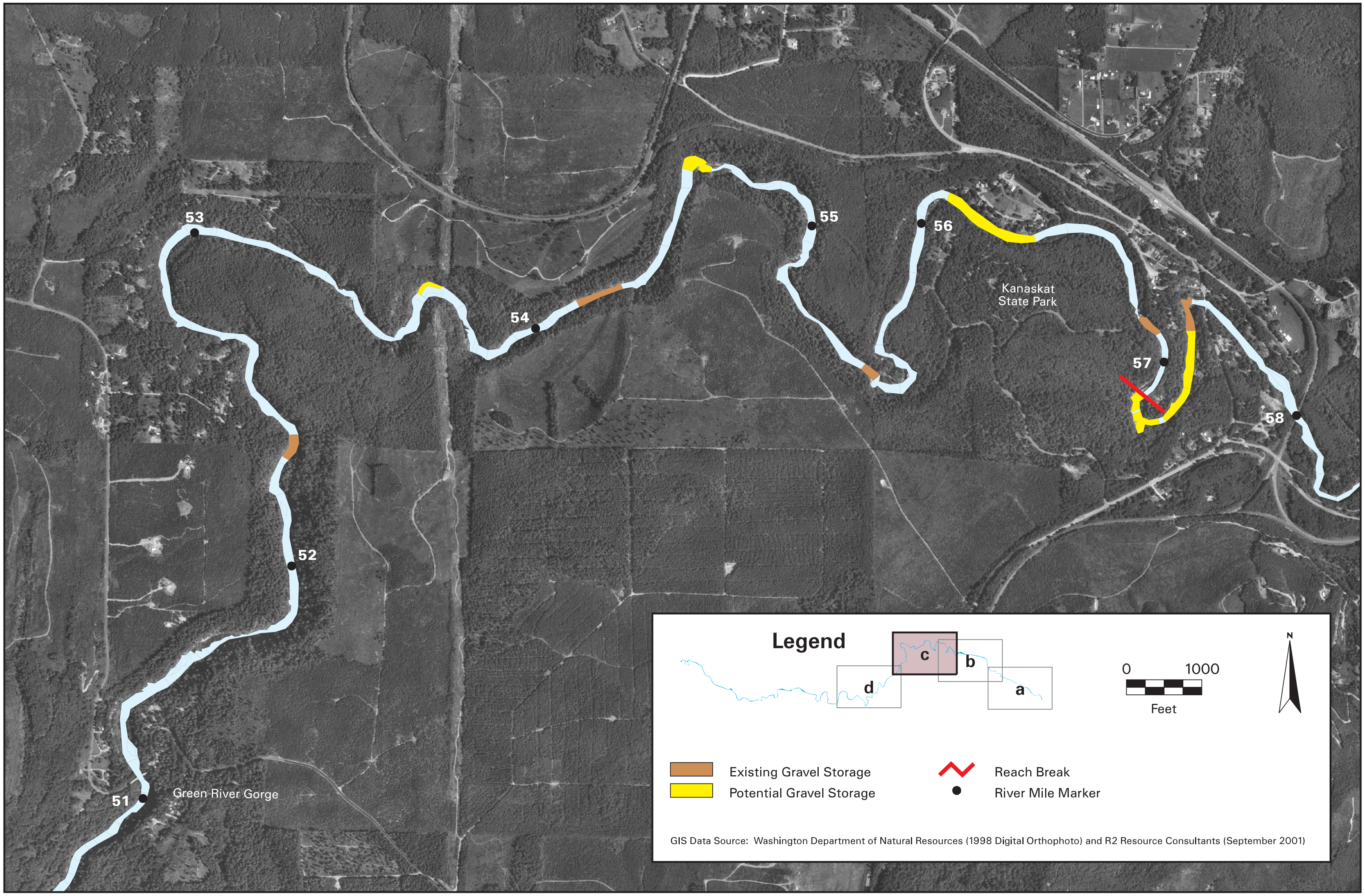
Potential gravel storage sites include low gradient pool tailouts, riffles with a low gradient relative to up and downstream habitat units, areas of divergent flow and the inside of meander bends where incipient point bars may be forming. Potential gravel storage sites were noted in the field and are depicted on Maps a to d. No attempt was made to quantify the volume of empty storage sites.



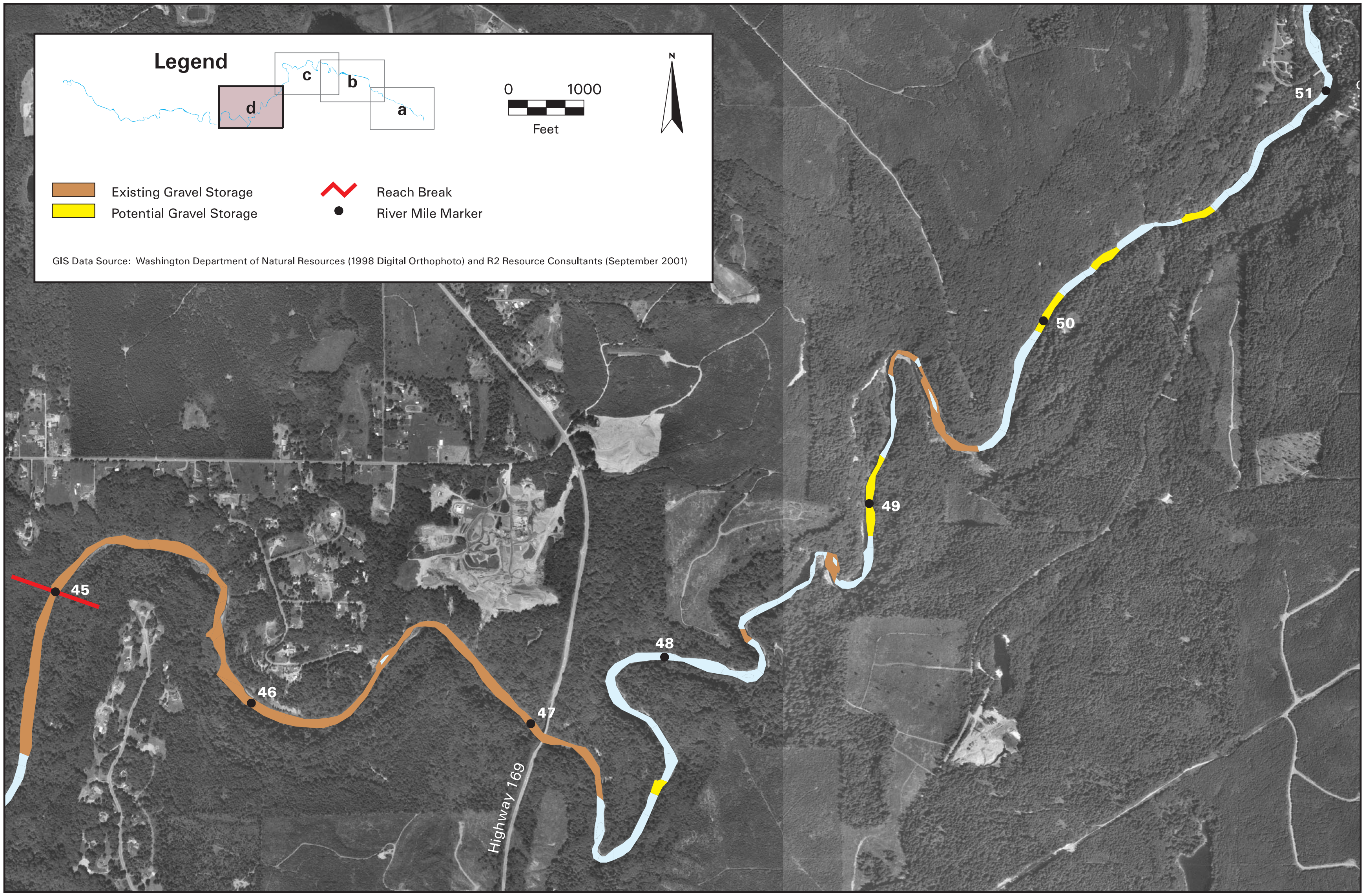
Map a. Middle Green River existing and potential gravel storage in Reach 1.



Map b. Middle Green River existing and potential gravel storage in Reach 2.



Map c. Middle Green River existing and potential gravel storage in Reach 3.



Map d. Middle Green River existing and potential gravel storage in Reach 3.